Nuclear Power

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Dungeness
Nuclear Power Station
pp 75—95

April 1961 monthly 3/6

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HEAD WRIGHTSON AT DUNGENESS

As a member of The Nuclear Power Group with a major stake in the construction of Dungeness Nuclear Power Station, Head Wrightson are responsible for:

- *The design of the steam raising units in conjunction with Gleeds, Chapman and Tom Thomson*
- *The supply of four of the eight heat exchangers for each of Stage 1 construction, approx. 70' 0" high x 20' 0" dia. and weighing 320 tons. These shall be fabricated at the Works at Thornaby-on-Tees, launched and towed to the Dungeness site.*
- *The detailed design and construction of the reactor cores; each core is composed of approx. 600,000 individual graphite components, approx. weight 1,000 tons.*
- *The design, manufacture and construction of the CO2 storage plant.*

With over a decade of experience in the design and manufacture of plant and equipment for nuclear development, Head Wrightson have supplied research reactors to Harwell, Dounreay, Australia, Denmark and Germany and are participating in the building of Bradwell and Latina in Italy.

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Nuclear Power

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VOL. 6 NO 60 APRIL 1961

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COVER PICTURE

The excavation and foundation for No. 2 reactor at Dungeness. In the background is the old lighthouse

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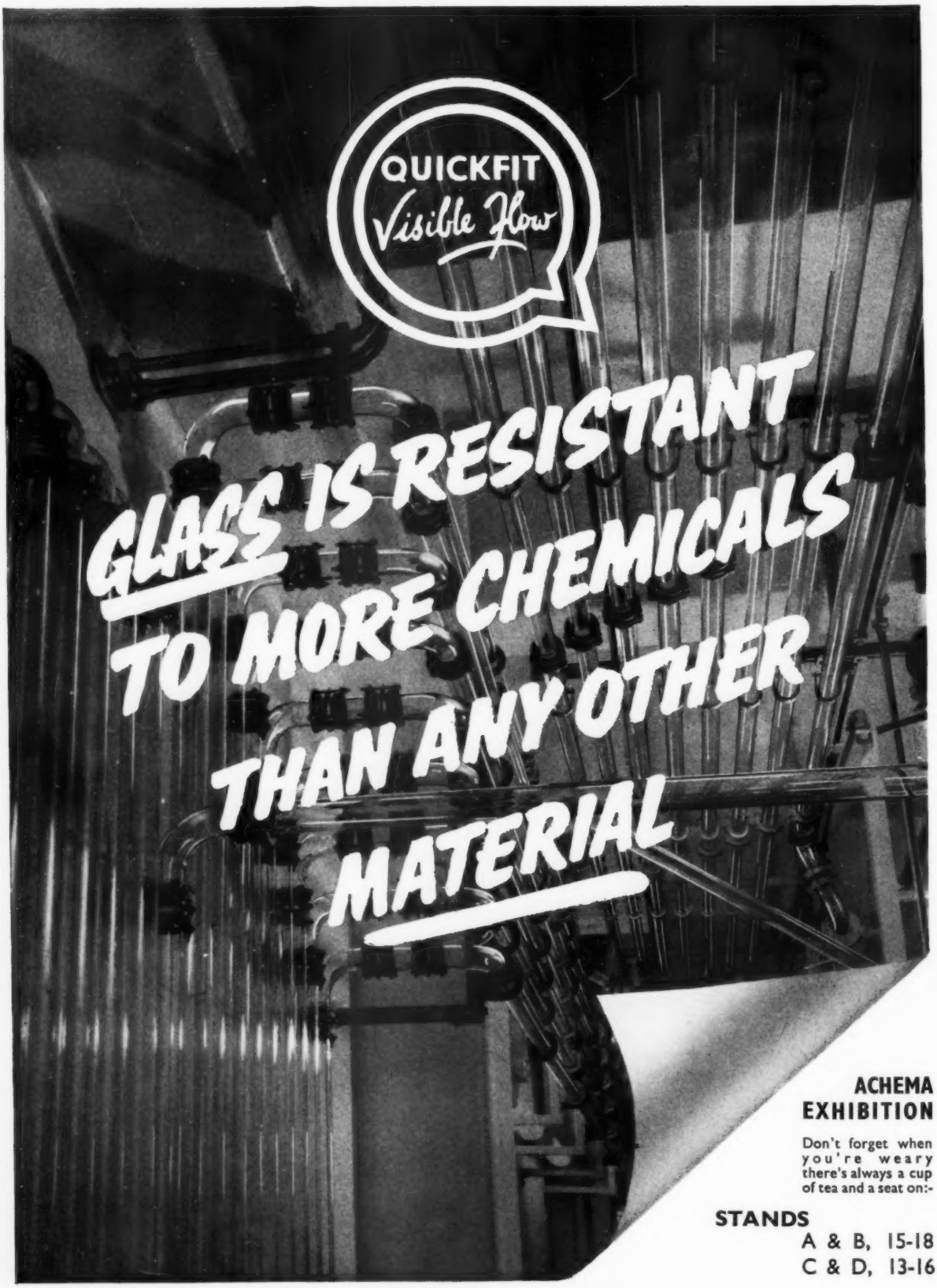

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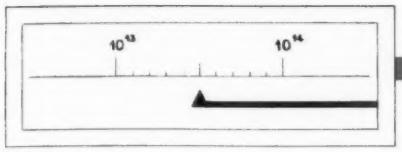

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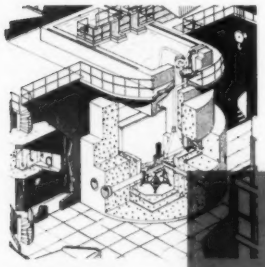

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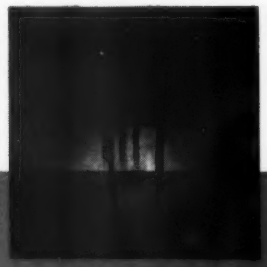

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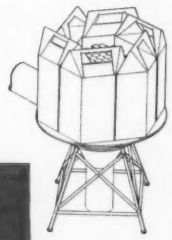

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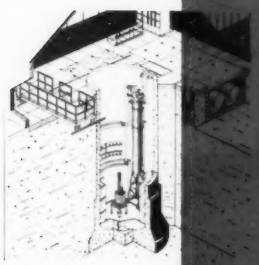

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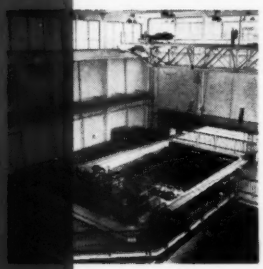

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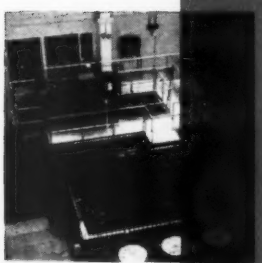

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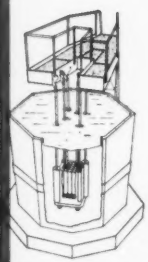

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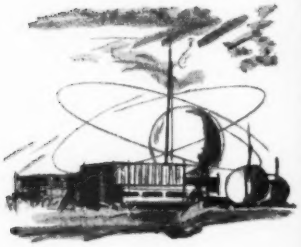

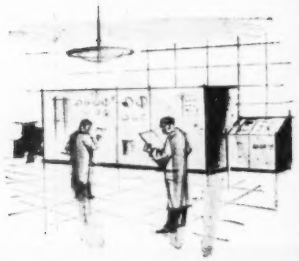

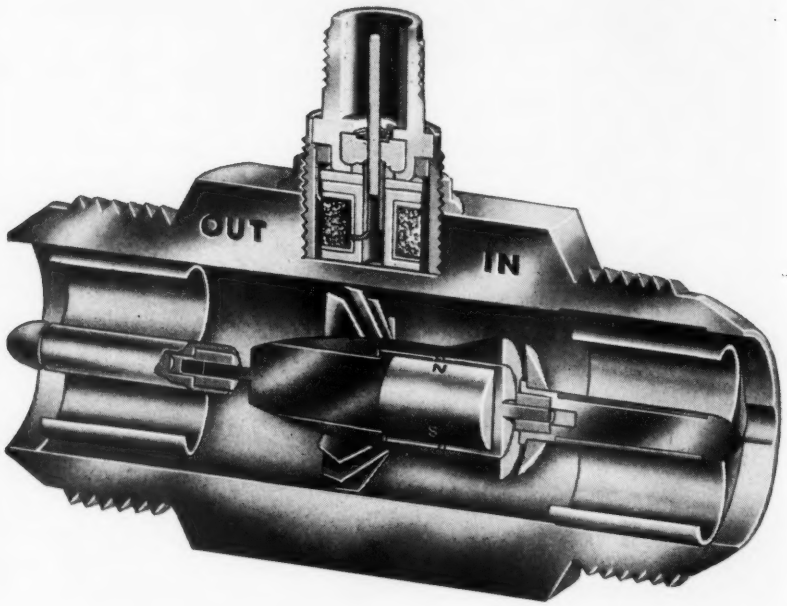

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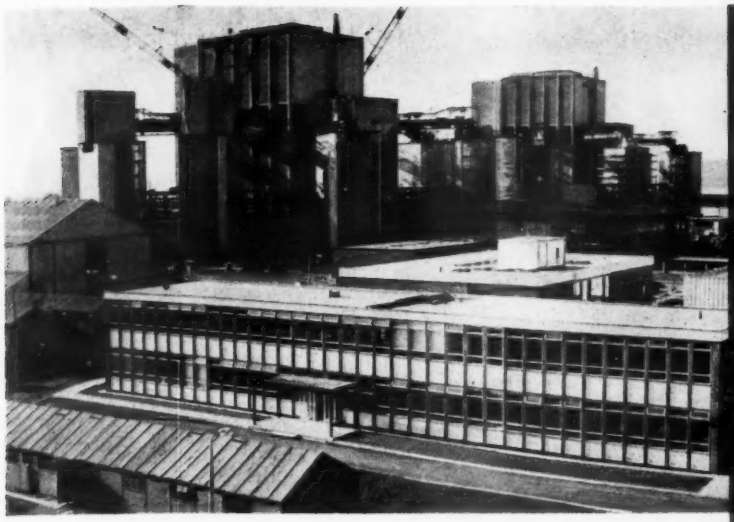

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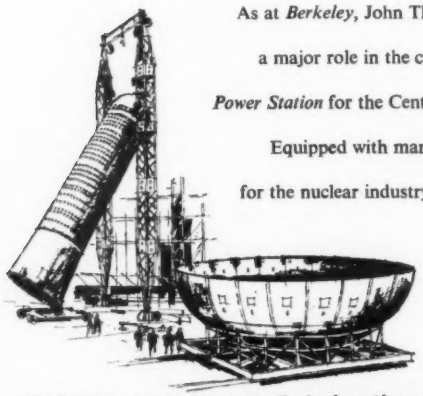

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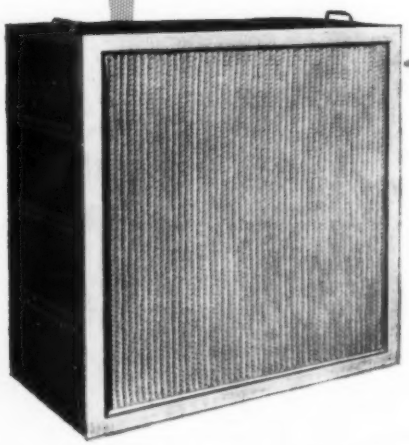

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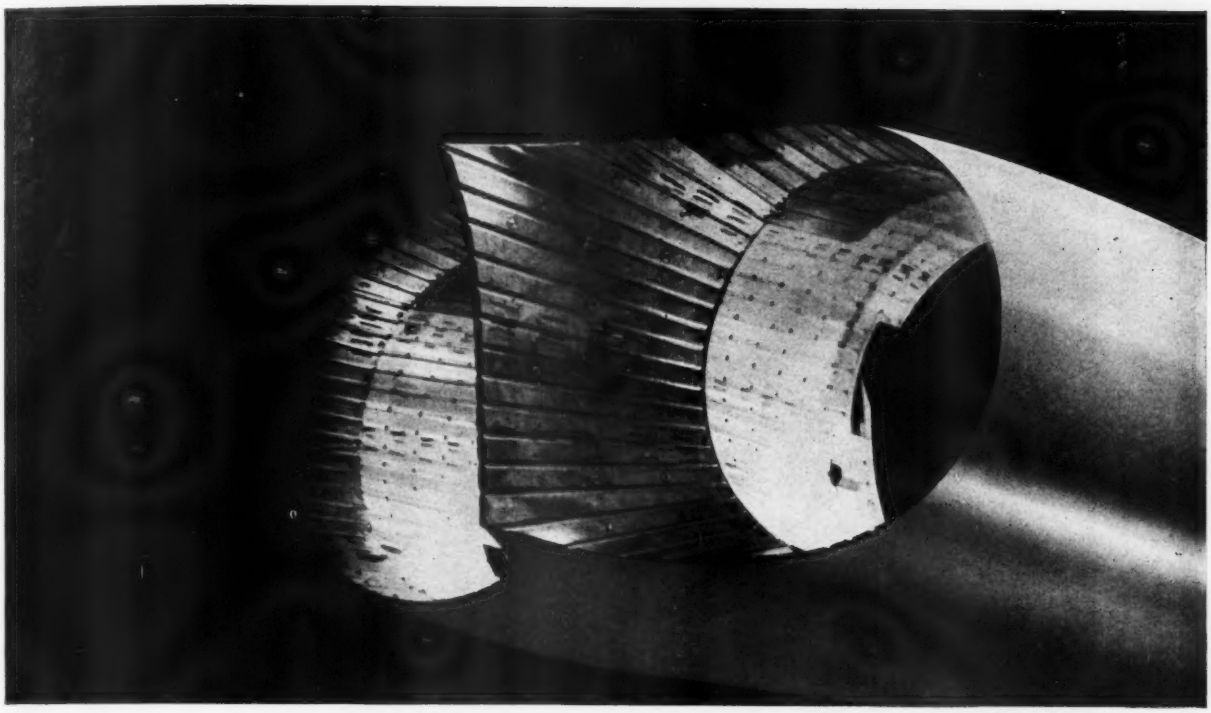

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O. P. G. 61

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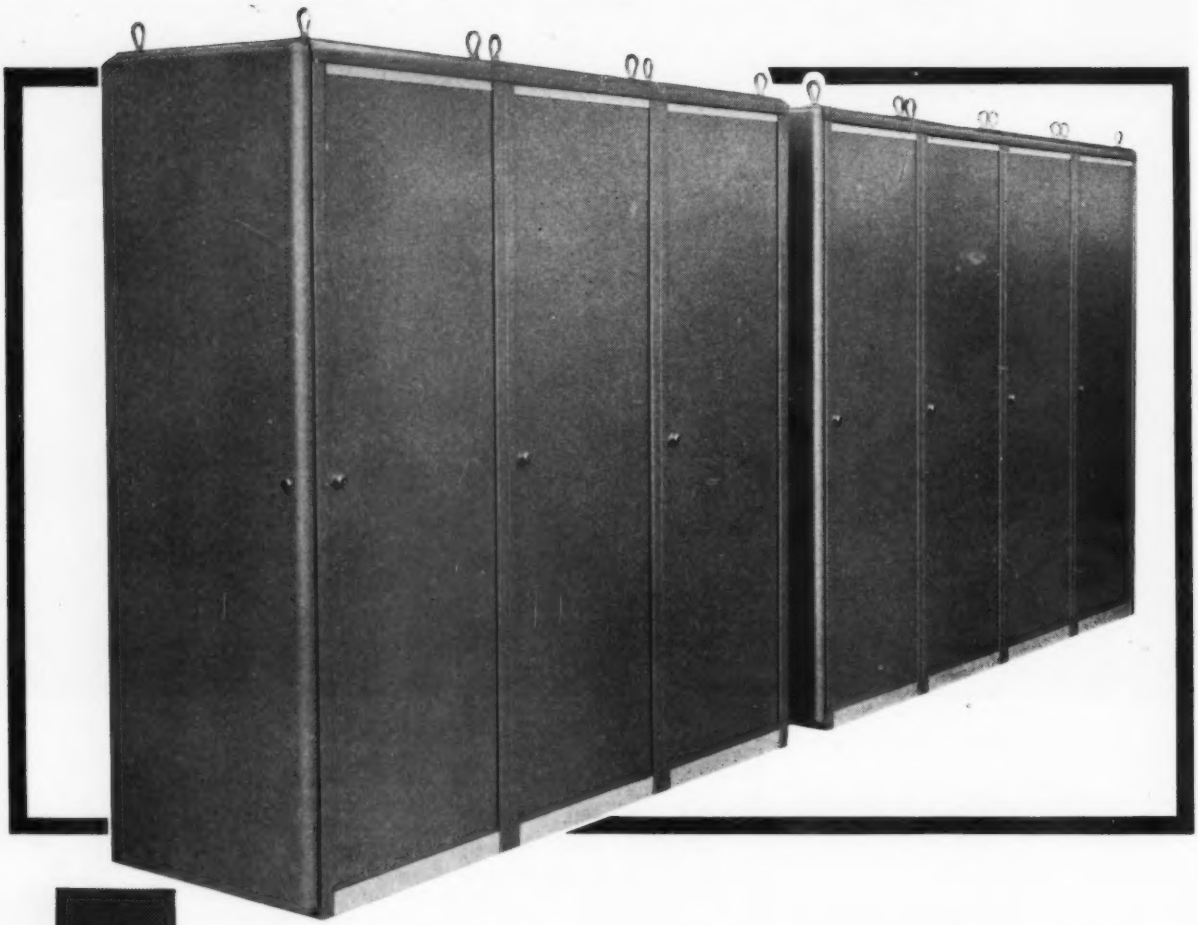

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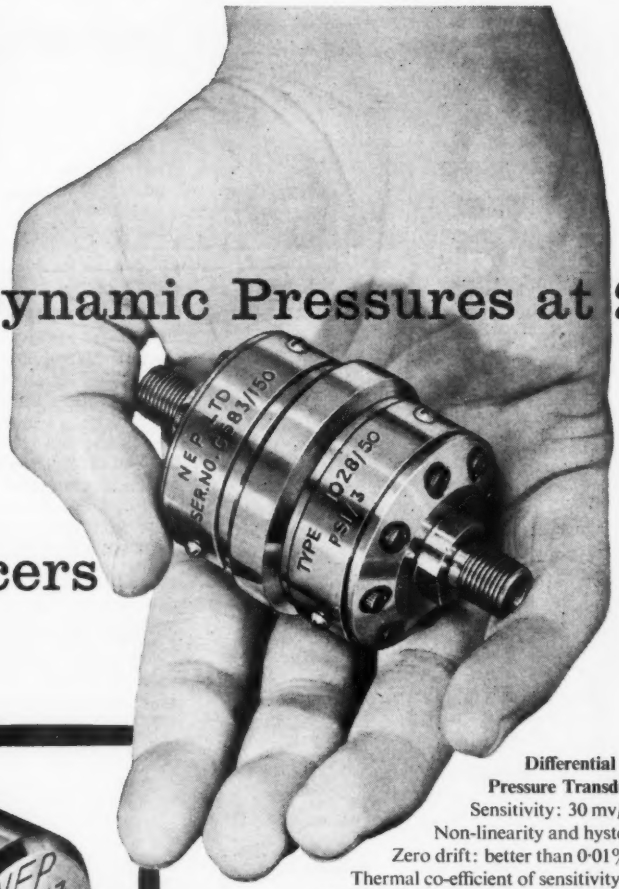
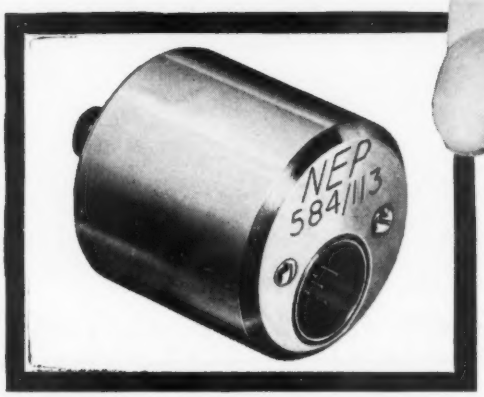


Differential Pressure Transducer. Type 1028
Sensitivity: 30 mv/v
Non-linearity and hysteresis: 1%
Zero drift: better than 0·01%/°C
Thermal co-efficient of sensitivity:
·02%/°C up to 200 p.s.i. ·05%/°C above 200 p.s.i.



Single Ended Pressure Transducer. Type 1029
Sensitivity: 60 mv/v Non-linearity and hysteresis: 1%
Zero drift: better than 0·01%/°C
Thermal co-efficient of sensitivity:
·02%/°C up to 200 p.s.i. ·05%/°C above 200 p.s.i.

Accuracy of measurement at temperatures up to 200°C . . . high output . . . low temperature drift — these are the three great advantages of N.E.P single-ended and differential pressure transducers. They are available with gauge or differential pressure ranges from 0-5 p.s.i. to 0-5000 p.s.i. They can be used with almost any fluids to give the most accurate dynamic pressure analysis.

N.E.P transducers are designed for use with the N.E.P oscillator-demodulator unit. This provides an output proportional to the fluid pressure, which can be used to operate controllers or recorded on the N.E.P process-free Direct Writing Galvanometer Recorder.

New Electronic Products Limited
A HONEYWELL AFFILIATE
Makers of scientific, medical and industrial instruments

Head Office and Works:
360 Kennington Road London SE11 Reliance 5161

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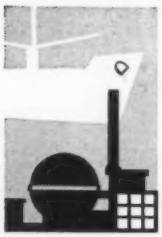
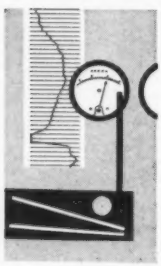
formula for leadership



Experience Founded originally in 1823 the Company has had the widest experience in the design and manufacture of all types of equipment for the handling of air and other gases. Blowers, exhausters, heaters, filters, dust and fume removal equipment, and of course, fans of all types, fall within this wide scope. Fans of every size and for every purpose, from Coal Mines to Aircraft Carriers, have been designed, manufactured and tested by Keith Blackman and installed in all parts of the world—experience unparalleled in the field.



Research Keith Blackman's lead in design is maintained by five separate research departments. Specialised facilities are available at Tottenham for the development and testing of axial fans, centrifugal fans and filtration equipment, while a metallurgical laboratory controls the quality of materials founded at Arbroath. Tottenham also possesses one of the most advanced acoustics laboratories in the world for the investigation of sound levels in all types of fan engineering equipment.
In addition, the company's generating station, as well as supplying power to the factory, is designed to produce a wide range of A.C. and D.C. supplies for the test beds.

Range The Keith Blackman range covers virtually every type of fan and blower in all sizes—axial types from 5 inch to 100 inch diameter, centrifugal types ranging from 1½ inch to 180 inch, and propeller fans from 6 inch to 72 inch diameter. Much equipment is designed for clients' specific requirements involving, frequently, the use of special materials including pvc. Other equipment is made for heating, cooling, washing, dust and fume extraction, filtration and air conditioning. *Five thousand fans of varying types are kept continuously in stock for quick delivery.*

Keith Blackman Ltd
(incorporating Blackman Export Co. Ltd.)
MILL MEAD ROAD, LONDON N.17 TOTTENHAM 4522

Leaders in the Fan Industry

Resources The company's three factories cover an area of 17½ acres, and employ over 1,800 people. The main Tottenham works produces small and medium units and includes drawing offices, test facilities and machine shops, as well as the sales and administration offices.
The Arbroath works deals with the production of the larger fans. Its iron and non-ferrous foundry plant supplies the whole of the company's casting needs.
The Edmonton Factory concentrates on light sheet metal and plate work and the fabrication of steel structures.
Virtually all components, including fan motors and bearing housings, are thus designed and manufactured within the organisation—a unique combination of resources.

Service Through the years the company has built up an enviable reputation for service at all stages. Sales representatives are all fully trained technical men capable of giving 'on the spot' advice on routine applications or special problems. The sales organisation operates from branches throughout the country backed by a staff of qualified sales engineers at Head Office.
Despatch of stock items, of which 5,000 units are kept continuously available, is possible in as little as four days. The Company has its own road transport fleet and direct rail connections from the main factory.

TAL545/1045

CASTROL INDUSTRIAL OILS

Castrol Industrial Oils chosen for Dungeness Nuclear Power Station

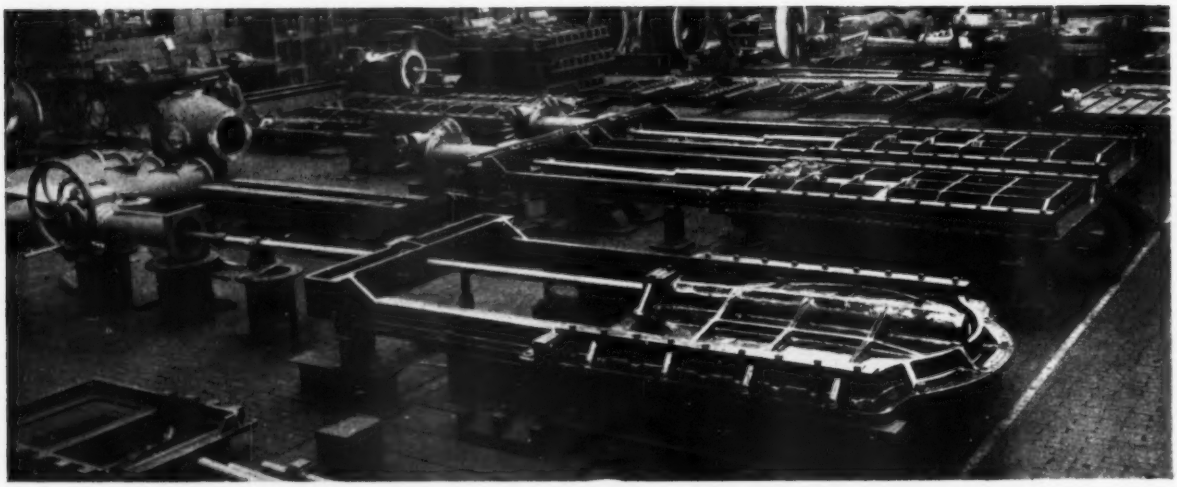
Sir Robert McAlpine & Sons Ltd., who are constructing Dungeness Nuclear Power Station, use Castrol Industrial Oils in all their equipment.

The Power Station is designed for a net output of 550 Mega watts and will be lubricated by Castrol Radiation Resistant as well as conventional lubricants.

Castrol INDUSTRIAL OILS

CASTROL INDUSTRIAL LIMITED, CASTROL HOUSE, MARYLEBONE ROAD, LONDON N.W.1.

GLENFIELD SLUICES



for Circulating Water Systems

are widely applied at the intakes, in the culverts and at discharge points of circulating water systems in thermal power stations.

Two types are available: a wall-mounting or open channel pattern and a dry-well culvert version. Both are robustly constructed in MEEHANITE cast-iron with bronze trim, and can be supplied for manual or power operation.

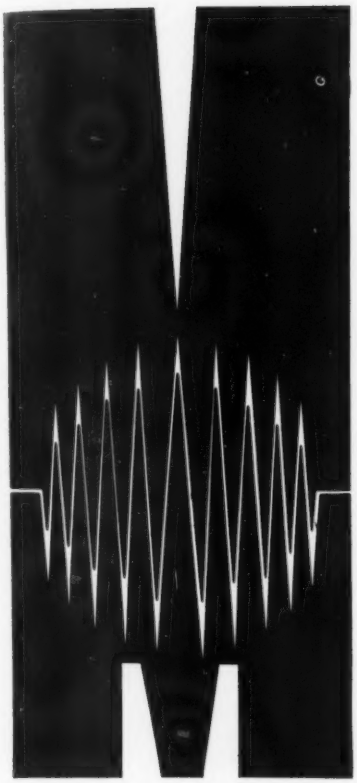
The illustrations show a variety of units in course of manufacture and the headstocks of several large dry-well units installed in an English station.

Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

Head Office & Works:

KILMARNOCK · SCOTLAND



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the first portable, "desk-top" 400-channel pulse height analyzer

Model 500
decimal printer

Model 404
pulse height analyzer

— the TMC Model 404

The new TMC Model 404 is the most portable pulse height analyzer you can own. Take it and use it anywhere. With its all-transistor, printed circuitry and 400-channel memory in a package just over a cubic foot, this analyzer is small enough to operate on your desk. *All* the instruments needed for an experiment can be carried easily by one person.

The Model 404 has a magnetic core memory that can be used in sub-groups of two or four; four separate inputs and associated amplifiers; internal pulse routing circuitry; pushbutton data transfer and display overlap; very low power requirements and many "system" advantages. And it can be used with the new solid state detectors.

For readout, use its companion unit, the Model 500 Decimal Printer; a high speed paper tape punch; strip chart or X-Y recorders; or an IBM electric typewriter.

LITERATURE ON REQUEST.

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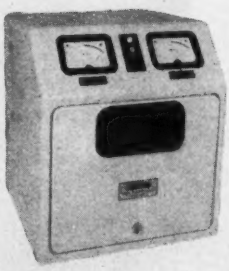
441 WASHINGTON AVENUE NORTH HAVEN, CONNECTICUT

EMI extends nuclear health coverage

WITH THE NEW SINGLE HAND MONITOR FOR THE SMALLER ESTABLISHMENT

The latest addition to EMI's range of Nuclear Health Devices . . . a Radiation Monitor for the smaller establishment where radio-active materials are handled.



* Transistors ensure accuracy and reliability, with low power consumption.
* Audio and visual alarms.
* Dual phosphor scintillation counters check contamination in as little as 5 seconds.

in addition to these brilliantly successful EMI units

THE HAND AND CLOTHING MONITOR

Specially designed to speed the checking of large numbers of staff, screening three workers at once for Alpha and Beta contamination of hands, clothing and footwear. Dual phosphor scintillation counters. Automatic correction for background radiation. Large numbers in use with UKAEA and authorities overseas.

THE PORTABLE MONITOR

A versatile instrument, whose range has now been extended by the addition of several interchangeable probes. Compact mobility plus high accuracy have been achieved by combining all-transistor circuitry with EMI dual phosphor technique. Battery or mains operation.

Write or telephone for a demonstration, or for the new Nuclear Health Short Form Catalogue:

EMI ELECTRONICS LTD

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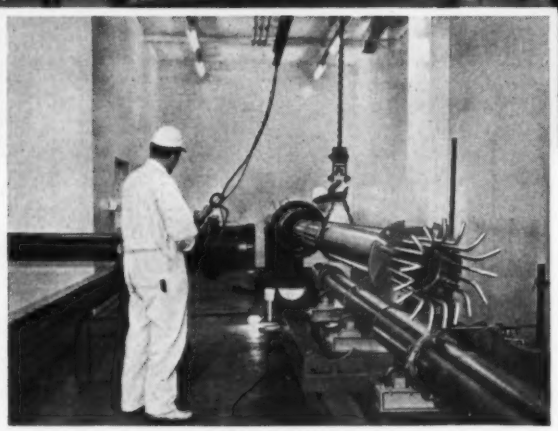
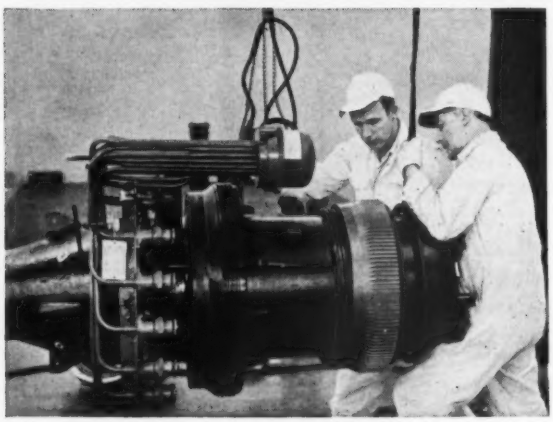
EMI





A Comprehensive Pipework Service

S & L, backed by a century of experience in the manipulation of pipework, has been associated for many years with power plant projects throughout the world.

In addition to manufacturing steel tubes the Company undertakes the design, supply and erection of complete pipework installations, including such ancillary equipment as supports, valves, pumps, tanks and lagging. When required, an efficient site testing service can be provided in which examination of welds is carried out by radiographic or ultrasonic methods.

S & L have supplied steam installations for the highest pressures and temperatures appertaining to power stations as well as large quantities of low and medium pressure pipework for all kinds of industrial plant. The Company also supplies special tubes for control rod standpipes in nuclear power plants, as shown in the illustrations, and undertakes the clean conditioning of nuclear components.

PED

PIPEWORK ENGINEERING DIVISION

STEWARTS AND LLOYDS LIMITED

Tubemakers for a Century

GLASGOW · BIRMINGHAM · LONDON

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G.E.C.
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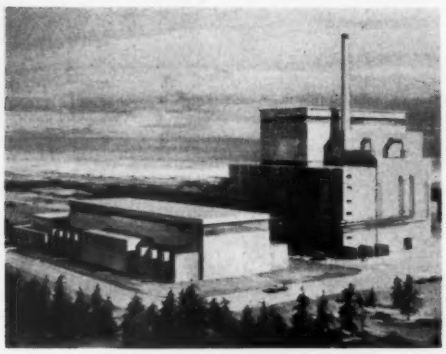
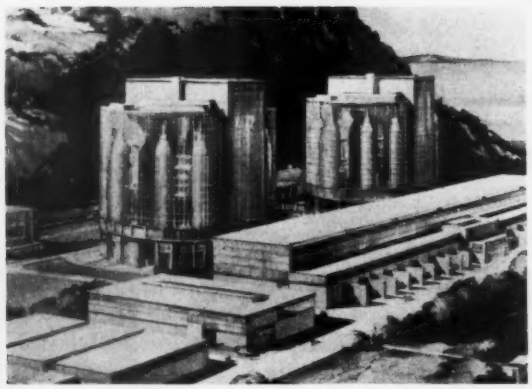
ON BOTH SIDES OF THE WORLD





Seventy miles from Tokyo, at Tokai-Mura, the British General Electric Co. of Japan Ltd. is building Japan's first full-scale earthquake-proof nuclear power station to designs produced by The General Electric Company Limited of England and Simon-Carves Ltd. When completed in 1965, this will represent a triumph for nuclear engineering. On the opposite side of the world, at Hunterston, G.E.C. and Simon-Carves are building one of the world's largest nuclear power stations to provide power for the South of Scotland Electricity Board. The combination of G.E.C. and Simon-Carves Limited makes available prodigious resources for atomic power development. As one of the largest electrical and mechanical engineering Companies in the world, G.E.C. itself employs over 70,000 people. Simon-Carves Limited is one of the leading British specialists in large steam-raising plant, coal cleaning and carbonising plant, and in chemical and civil engineering. The Group is able to design, build and install nuclear power stations anywhere in the world, to suit local conditions.

G.E.C.
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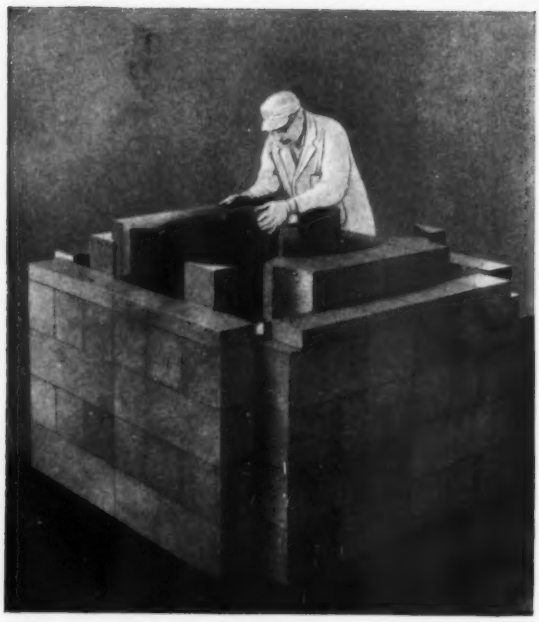
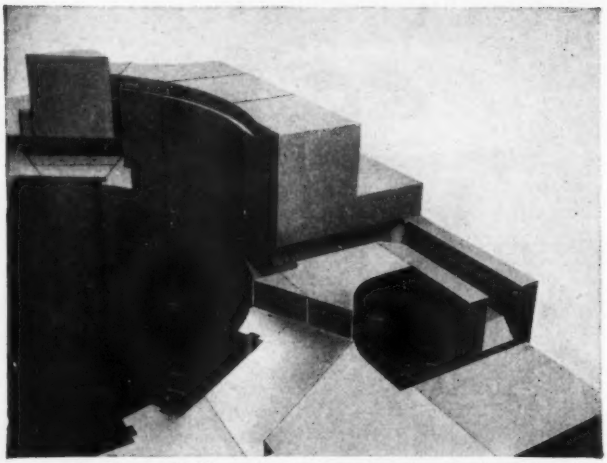
ATOMIC ENERGY GROUP

HEADQUARTERS
THE GENERAL ELECTRIC COMPANY LIMITED
OF ENGLAND · ERITH · KENT





Sections of a "Jason" reactor recently completed for the Hawker-Siddeley Nuclear Power Co. Ltd.

GRAPHITE MACHINING

Powell Duffryn Carbon Products Limited— the leading machinists of Nuclear Graphite.

Official Graphite machinists for the General Electric Co. Ltd. Current contracts cover important work at: Hunterston, Berkeley, Bradwell; also for Hawker-Siddeley Nuclear Power Co. and U.K. Atomic Energy Authority.

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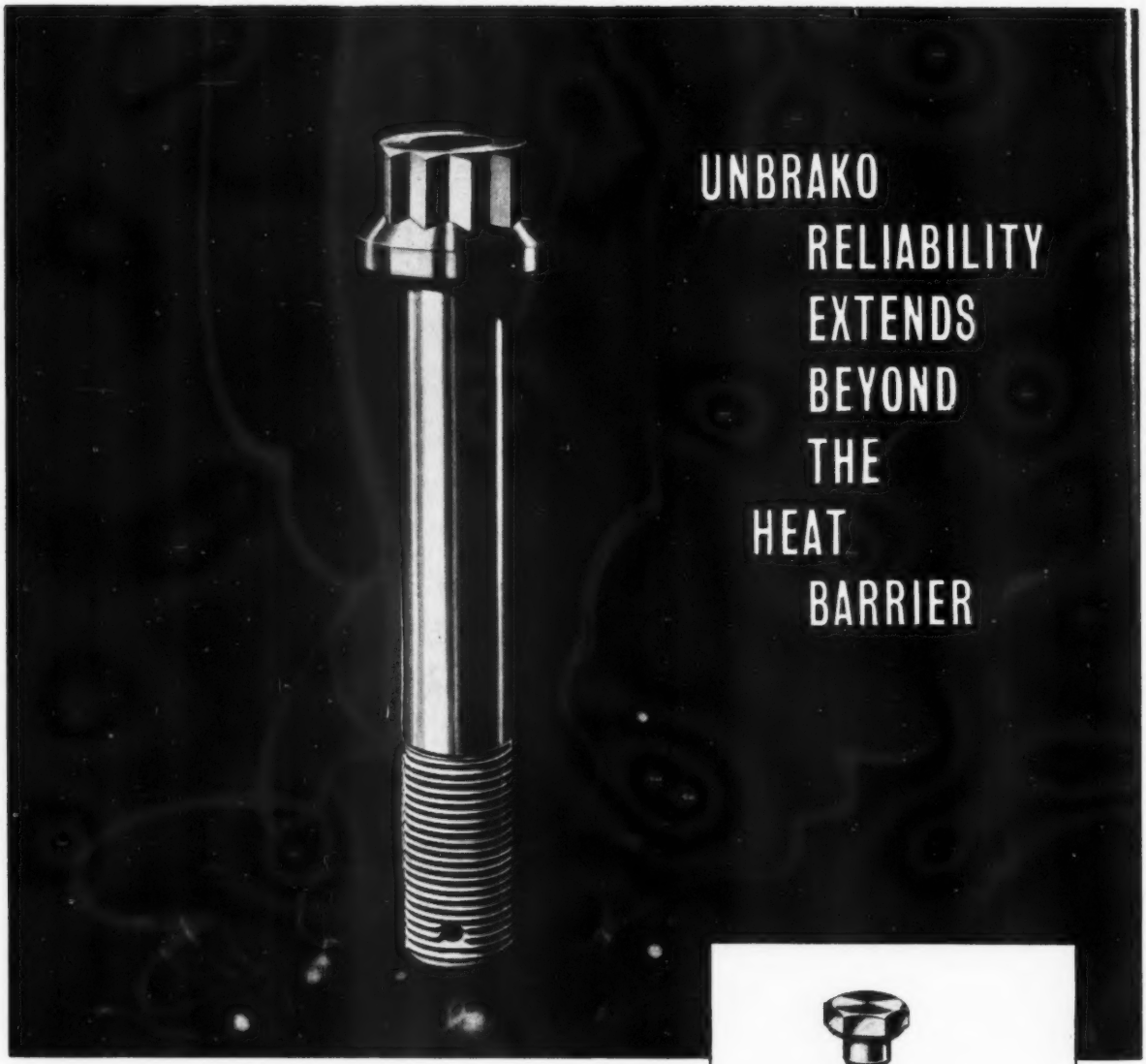

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We live in exciting times. Man's knowledge has assumed seven league boots and leads him across fresh frontiers every day. But new territory is fraught with new dangers, many of which can only be guessed at. The next stepping stone for our aircraft is the heat barrier. Here, as before, complete safety will depend on the reliability of every component part used. Unbrako make fasteners for these aircraft of tomorrow. We do not rely only on our long experience in this field. In our Advanced Design Division, a team of highly skilled engineers are constantly probing and testing, helping us to make fasteners that do more than satisfy today's requirements — fasteners with a safe place in the future.

UNBRAKO AD*

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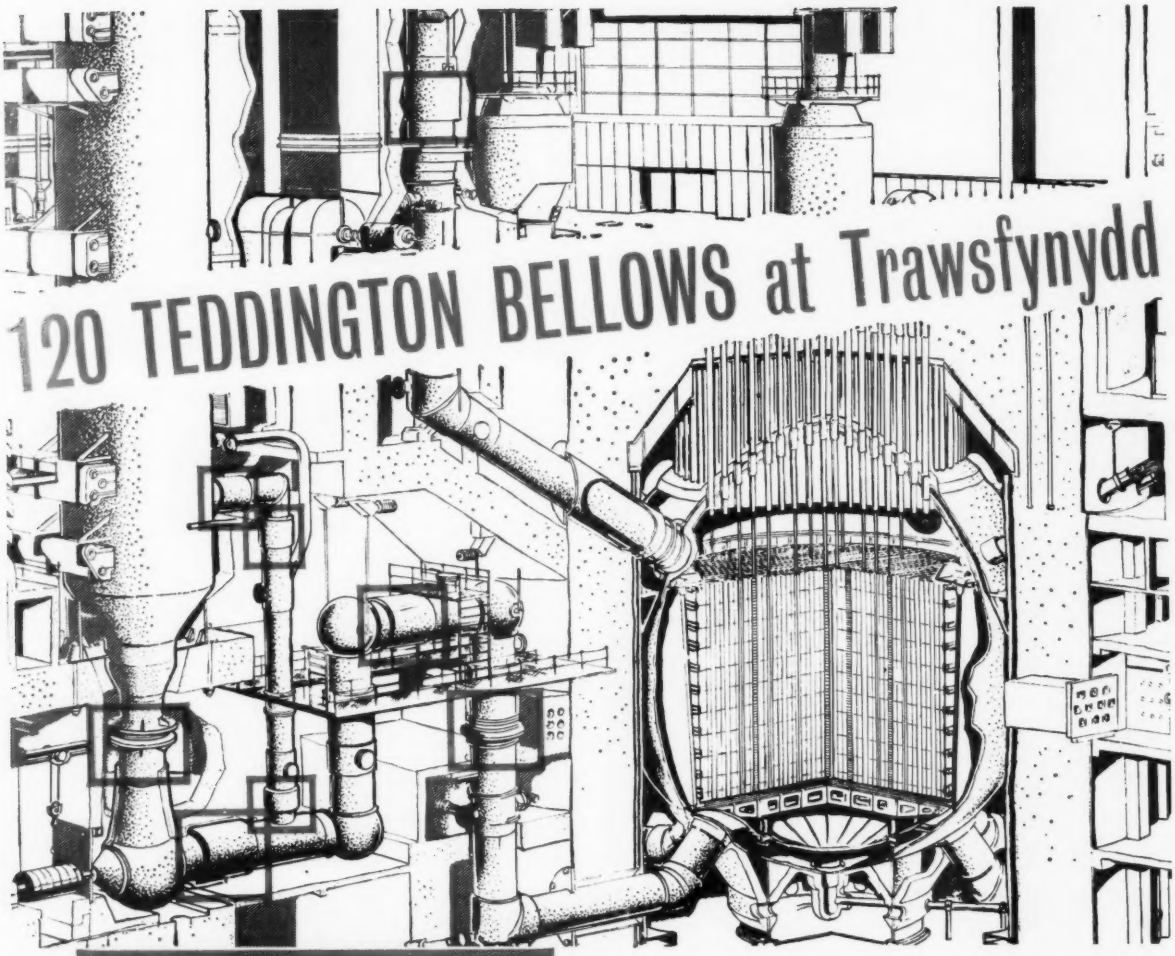
120 TEDDINGTON BELLOWS at Trawsfynydd



By courtesy of 'NUCLEAR POWER'

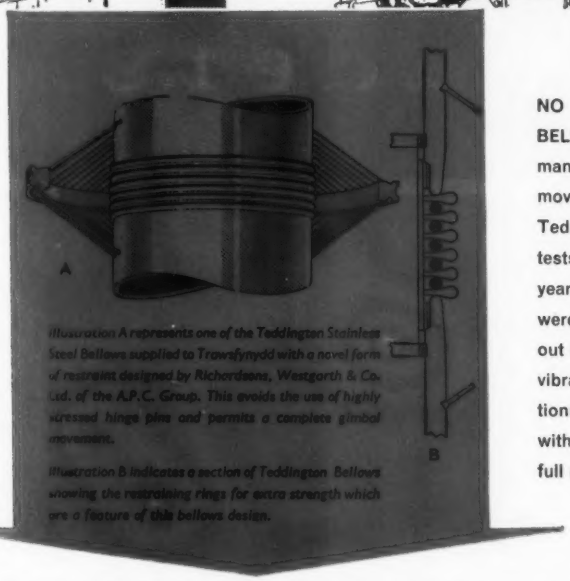


Illustration A represents one of the Teddington Stainless Steel Bellows supplied to Trawsfynydd with a novel form of restraint designed by Richardsons, Westgarth & Co. Ltd. of the A.P.C. Group. This avoids the use of highly stressed hinge pins and permits a complete gimbal movement.

Illustration B indicates a section of Teddington Bellows showing the restraining rings for extra strength which are a feature of this bellows design.

NO LESS THAN 84 BELLOWS 66″ diameter and 36 BELLOWS 42″ diameter, all of butt-welded stainless steel manufacture, are being fitted at Trawsfynydd to take up movement in the CO_2 cooling gas ducts.

Teddington secured this order only after many exhaustive tests including an accelerated life test equivalent to 20 years full operation. In addition, the larger size bellows were subjected to over-pressure tests of 1580 p.s.i.g. without developing a leak. Wherever pipe-work is subjected to vibration and movement in any direction owing to conditions of temperature and pressure, a Teddington bellows with a suitable end fitting will solve the problem. Write for full details of our range.

TEDDINGTON AIRCRAFT CONTROLS LIMITED

(INDUSTRIAL BELLOWS DIVISION),
TEILO WORKS, PONTARDULAIS, SWANSEA.
Tel. : Pontardulais 591.

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TNPG - leaders in N

DUNGENESS 550 MW* · BRADWELL 300 MW* · BERKELEY 275 MW* · LATINA (ITALY) 200 MW**

* For the Central Electricity Generating Board
** In conjunction with AGIP Nucleare, Milano

At Bradwell and Berkeley, Britain's first two commercial nuclear power stations, the No. 1 reactors are approaching completion and will soon be ready for fuel loading.

In 1962, Italy's first nuclear power station at Latina will go critical.

These are stations designed and now being built by The Nuclear Power Group. The cumulative experience from such projects - coupled with the extensive research, development, production and construction resources of ten major industrial concerns - has gained for T.N.P.G. the award of Dungeness, the most efficient nuclear power station yet designed. With current orders for 1325 MW of nuclear power, T.N.P.G. are, indeed, leaders in nuclear power.

THE NUCLEAR POWER GROUP · RADBROKE HALL · KNUTSFORD · CHESHIRE

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TNPG/5

1 **Dungeness:** *The excavations and foundations for No. 1 and 2 reactors*

2 **Berkeley:** *No. 1 and 2 reactors nearing completion*

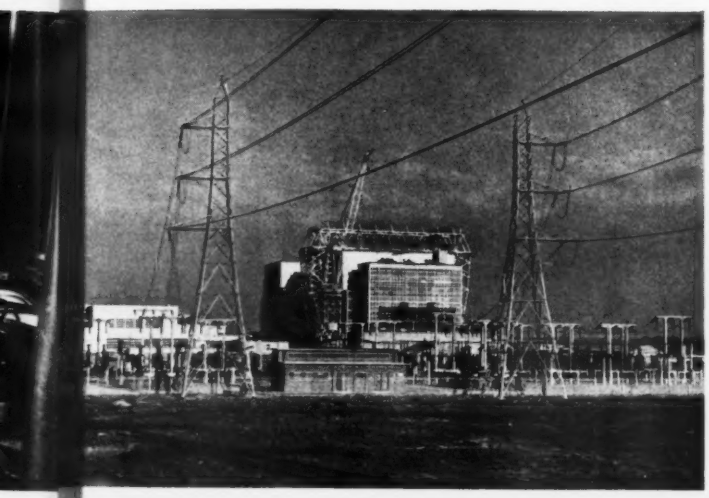
3 **Berkeley:** *Trial fuel loading in No. 1 reactor*

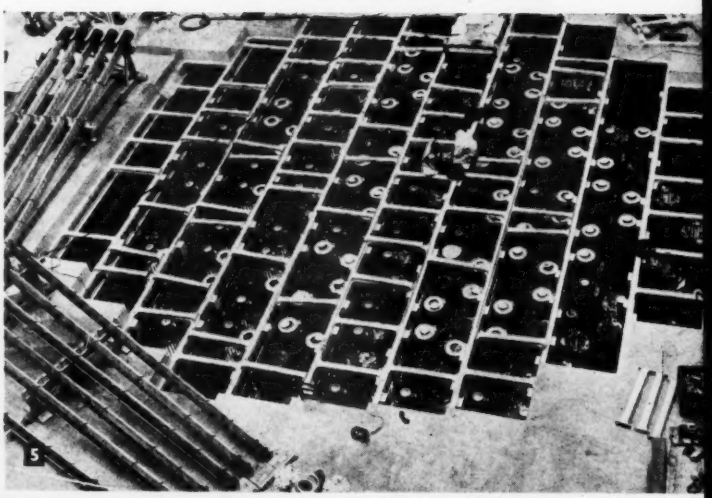
4 **Bradwell:** *A view of the station from the switchyard area*

5 **Bradwell:** *The pile cap area—No. 1 reactor*

6 **Latina:** *Installing tube banks in one of the six boilers*

7 **Latina:** *The turbine house (left) and the reactor with six boilers installed (right)*





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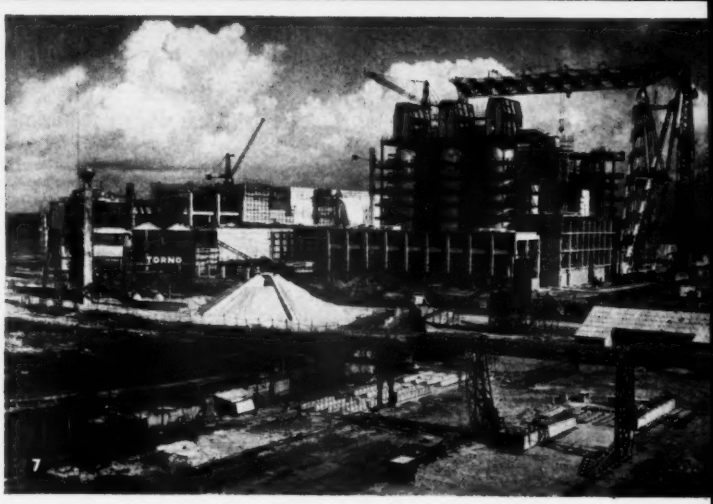

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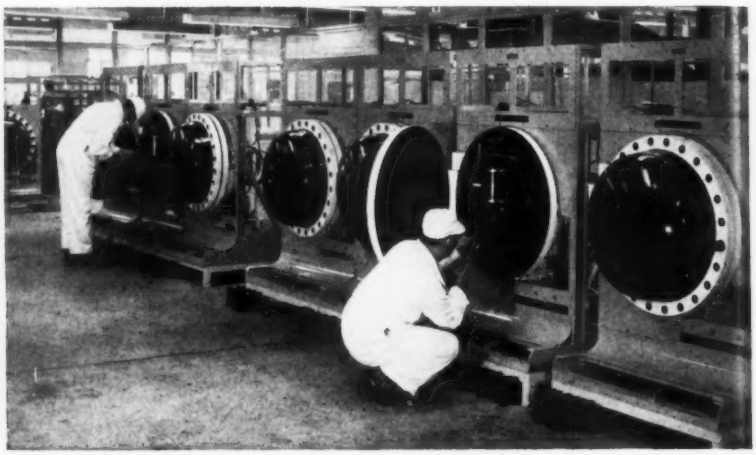
Nucleonic Achievement

Clean area precision assembly



Clean area BSD equipment manufacture

Plessey Nucleonics Limited is engaged, exclusively, in the design and manufacture of nuclear equipment and instrumentation; this includes BSD and flux scanning systems for reactors, radiation detectors of all types, and instruments for process control, health and defence.

The production of so much that is complementary in nuclear instrumentation has established an accumulation of scientific skills which is quite unique in the world of nucleonics. These techniques and knowledge are now offered for the development of new projects.

Plessey nuclear instrumentation has gained *world wide acceptance*. The Company's BSD equipment has, for example, been chosen for every one of these reactors:

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PNL102

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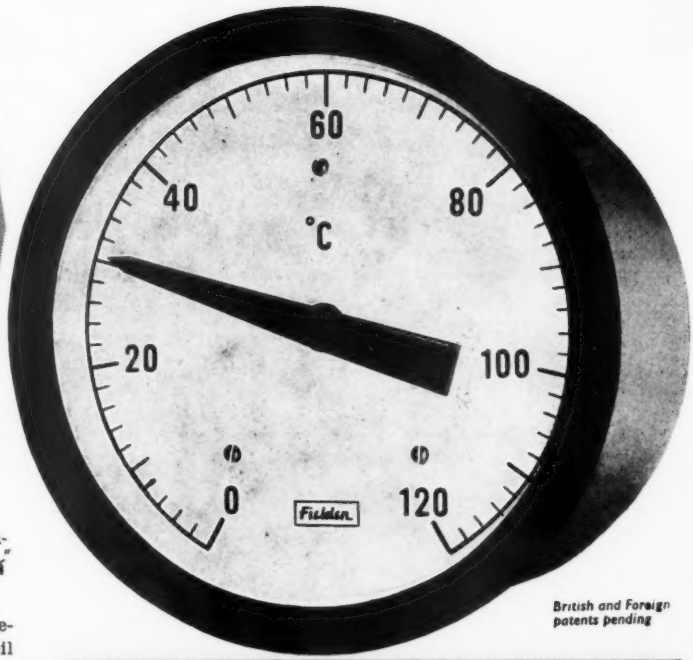


British and Foreign patents pending

VERY ROBUST. Sealed 6" diameter instrument, with measuring bulb in ¼" diameter stainless steel sheath.

LOW COST. A practical and economic replacement for filled systems and moving coil instruments — send for price list.

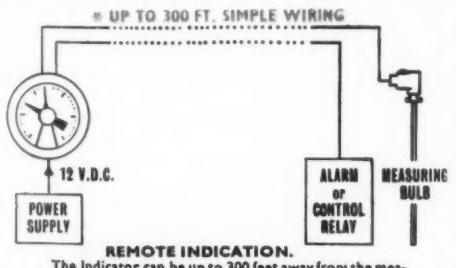
TRANSISTORISED. Exceptional reliability with a printed circuit and robust motor driven indicating pointer. 12 volt battery or mains supply.

EASILY FITTED. Simple clamp mounting with robust terminals. No fragile capillary tubes or expensive compensating cable — simple wiring only required.

ACCURATE AND RAPID RESPONSE. Reproductibility better than 0·25% on 13" scale, response time 1 second.

73 TEMPERATURE RANGES in °F and °C for temperatures up to 850°C.

'BIKINI' REG'D TRADE MARK TEMPERATURE INDICATOR



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The Indicator can be up to 300 feet away from the measuring point with no effect on calibration and accuracy.

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Differential 0·5°C. Includes similar features to the Bikini Indicator. Send for specification sheet BIK. 1 and price list.

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The Indicator can be supplied with an adjustable control contact for use with local or remote alarm or control relay.

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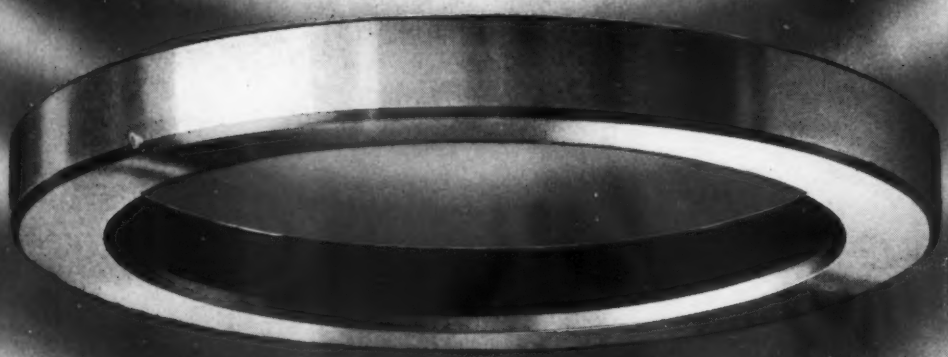

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HIGH SPEEDS COUPLED WITH
HIGH FLUID TEMPERATURES
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Illustrated is a sectional view of a C.B.A. type seal with contact ring

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Exceptional cold strength at 24 hours and permanent residual strength for structural purposes at elevated temperatures.

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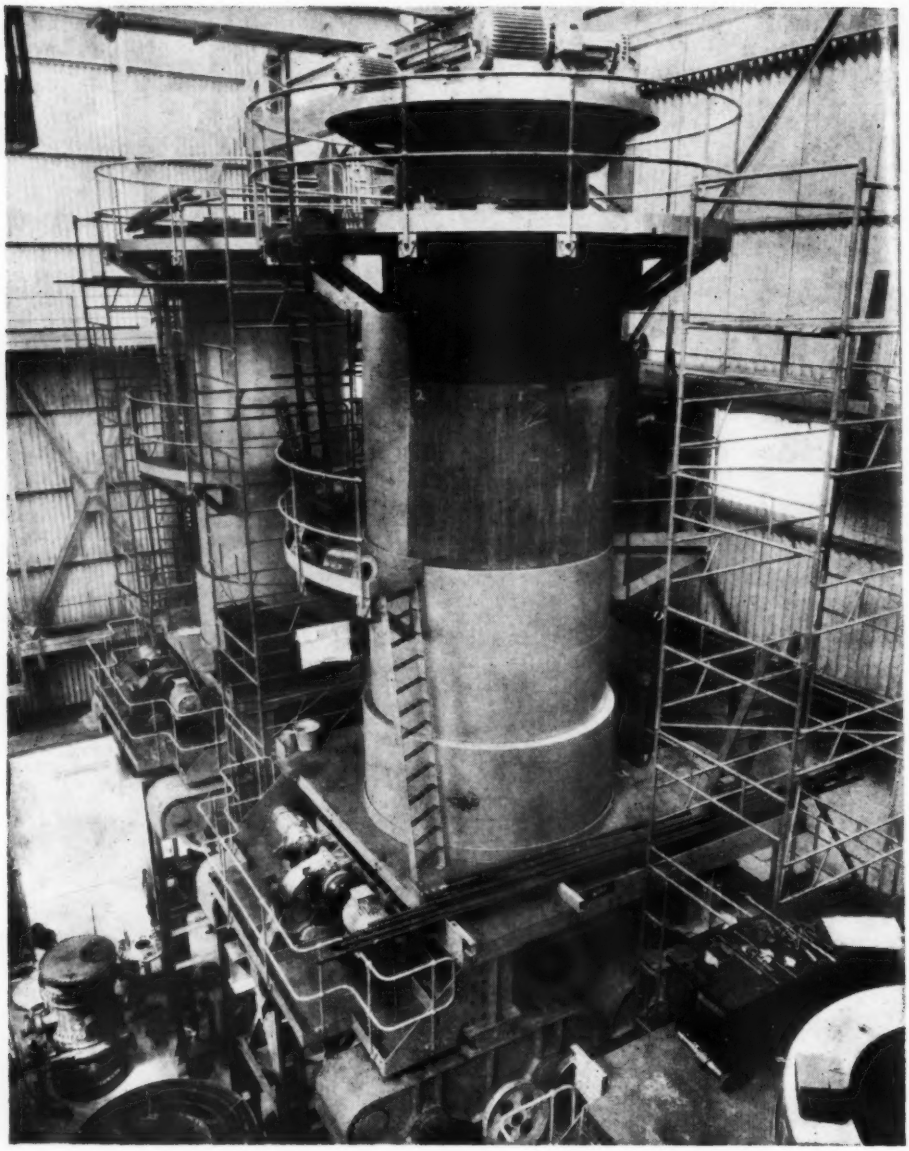
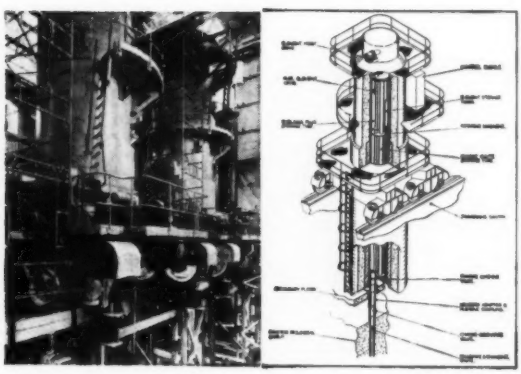
For operating temperatures up to 1800°C, or when a refractory resistant to reducing conditions is required, use Super-Duty Refractory Concretes made with SECAR 250, a pure white calcium-aluminate cement, free from iron oxides. Write for details.

AP122



NUCLEAR REACTOR CHARGE-DISCHARGE EQUIPMENT FOR BRADWELL



Four 400 ton Reactor Charging Machines are now being assembled in a special 80 feet high erection bay at Bristol.

Running on massive traversing gantries – also supplied by Strachan & Henshaw – they will carry out the charging of the Reactors with fuel elements and also the discharging operation.

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Rio Tinto, producers of uranium and thorium, will play an important part in the future industrial use of nuclear power through the following companies:

Rio Algom Mines Limited, CANADA has amalgamated the four Canadian uranium mining companies under Rio Tinto's management, to form the largest uranium producing company in the world.

Mary Kathleen Uranium Ltd., AUSTRALIA managed by Rio Tinto in Australia, is now in full production and supplying uranium for Britain's nuclear power stations.

Rio Tinto Dow Limited, CANADA Rio Tinto and the Dow Chemical Company of Canada are collaborating in uranium processing and producing thorium as a by-product of uranium.

Thorium Limited, UNITED KINGDOM owned by Rio Tinto and Dow Chemie A.G. processes crude thorium materials and markets a variety of refined thorium and rare earth compounds.

Nukem–Nuklear-Chemie und-Metallurgie G.m.b.H., GERMANY has been formed by Deutsche Gold-und Silber- Scheideanstalt (Degussa), Rio Tinto, Metailgesellschaft and Mallinckrodt Chemical Works to manufacture nuclear fuel materials and fuel elements.

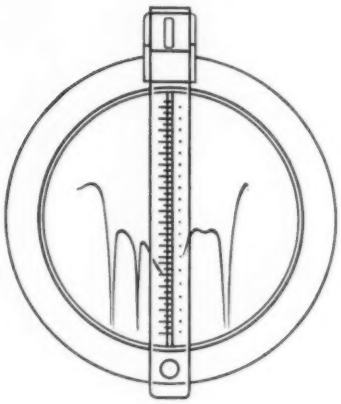
Austro-Chematom Kernbrennstoff G.m.b.H., AUSTRIA formed by the Osterreichische Stickstoffwerke A.G. in association with Rio Tinto and Degussa to manufacture nuclear fuel materials and fuel elements.

RIO TINTO MANAGEMENT SERVICES (U.K.) LIMITED
BARRINGTON HOUSE, 59 GRESHAM STREET, LONDON E.C.2.

Circle **No 35** on reply card for further details

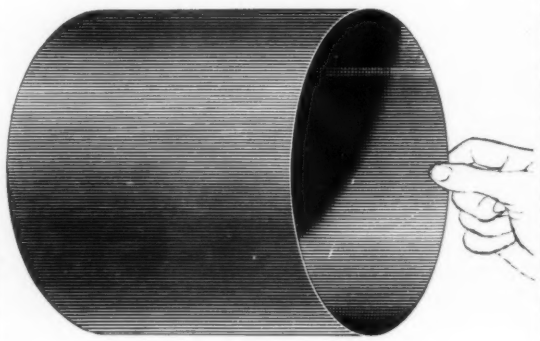
Some recent developments in manufacturing techniques and special applications of tubes in a variety of metals . . .

No. 16 OF A SERIES BY ACCLES & POLLOCK



The trend towards higher operating pressures and temperatures in the aircraft and atomic energy industries is causing designers to be increasingly concerned about the quality and soundness of the material being used. In addition to all the general methods of non-destructive examination of materials we can test materials by the ultrasonic and eddy current flaw detection methods. *Send for Information Sheet No. 5.*

Thin wall tubing, particularly in stainless steel, has a range of application that steadily increases, and we can produce tubes with wall thicknesses ranging from .003″ at 1″ o/d to .009″ at 8″ o/d.



Designers have a habit of asking for the impossible, but in a surprising number of cases Accles & Pollock produce an answer that enables the production people to translate the concept on the drawing-board into a physical, functional form. Accles & Pollock welcome all such opportunities to co-operate in developing new applications in the form of tubes and tubular sections.

Accles & Pollock

Technical Information Sheets discussing tubes and their applications are available on request.

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TBW 313

The Hayward Tyler glandless circulating pumps for the C.E.G.B's Nuclear Power Station at Trawsfynydd in Merionethshire, North Wales, are of inverted construction with the water-filled motors underneath the pump impellers. Under certain conditions this arrangement offers important advantages.

Trawsfynydd Power Station has a scheduled output of 500 MW. The high and low pressure circulating systems operate at 1000 and 325 P.S.I.G. and a total of forty-eight Hayward Tyler glandless circulating pumps are being supplied through International Combustion Ltd.

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& CO. LTD., P.O. BOX 2, LUTON. PHONE: 6820

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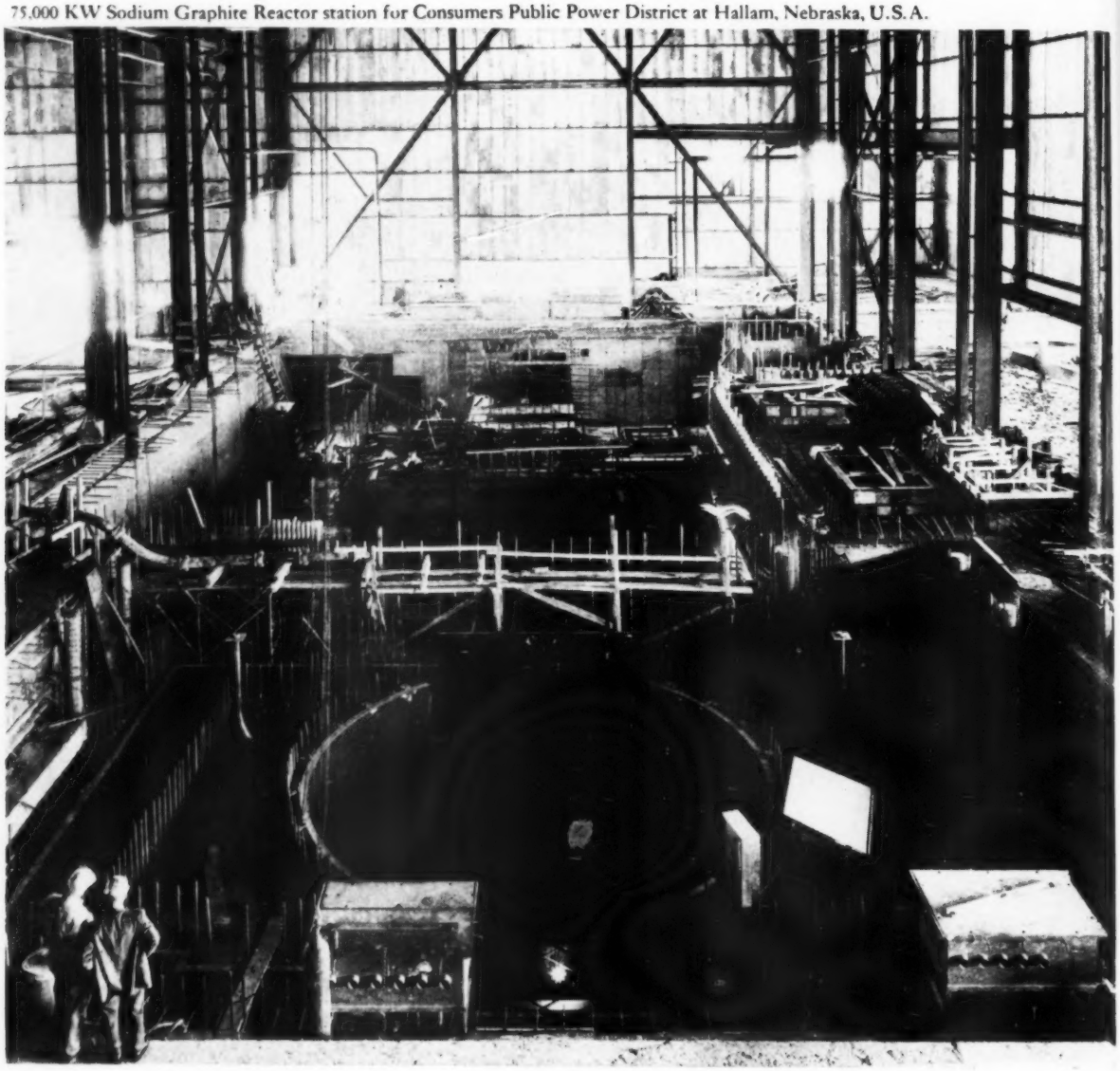
75,000 KW Sodium Graphite Reactor station for Consumers Public Power District at Hallam, Nebraska, U.S.A.



The Peaceful Atom

Helping the world double its power supply in the next ten years

The fuel of the future is in the atom. But even now, lights are burning, wheels are turning, thanks to atomic fuel. Atomics International, a world-wide leader in high-performance reactor systems, has over 15 years' experience in designing, constructing, and operating reactors. Two of the world's most advanced atomic power stations are now being built by AI under U.S. Atomic Energy Commission programs. The wealth of experience and facilities at AI will help the world's power-producing companies in their plans to double the supply of electricity in the next ten years.

ATOMICS INTERNATIONAL DIVISION OF NORTH AMERICAN AVIATION, INC.

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Affiliated with: INTERATOM, Bensberg/Cologne, Federal Republic of Germany

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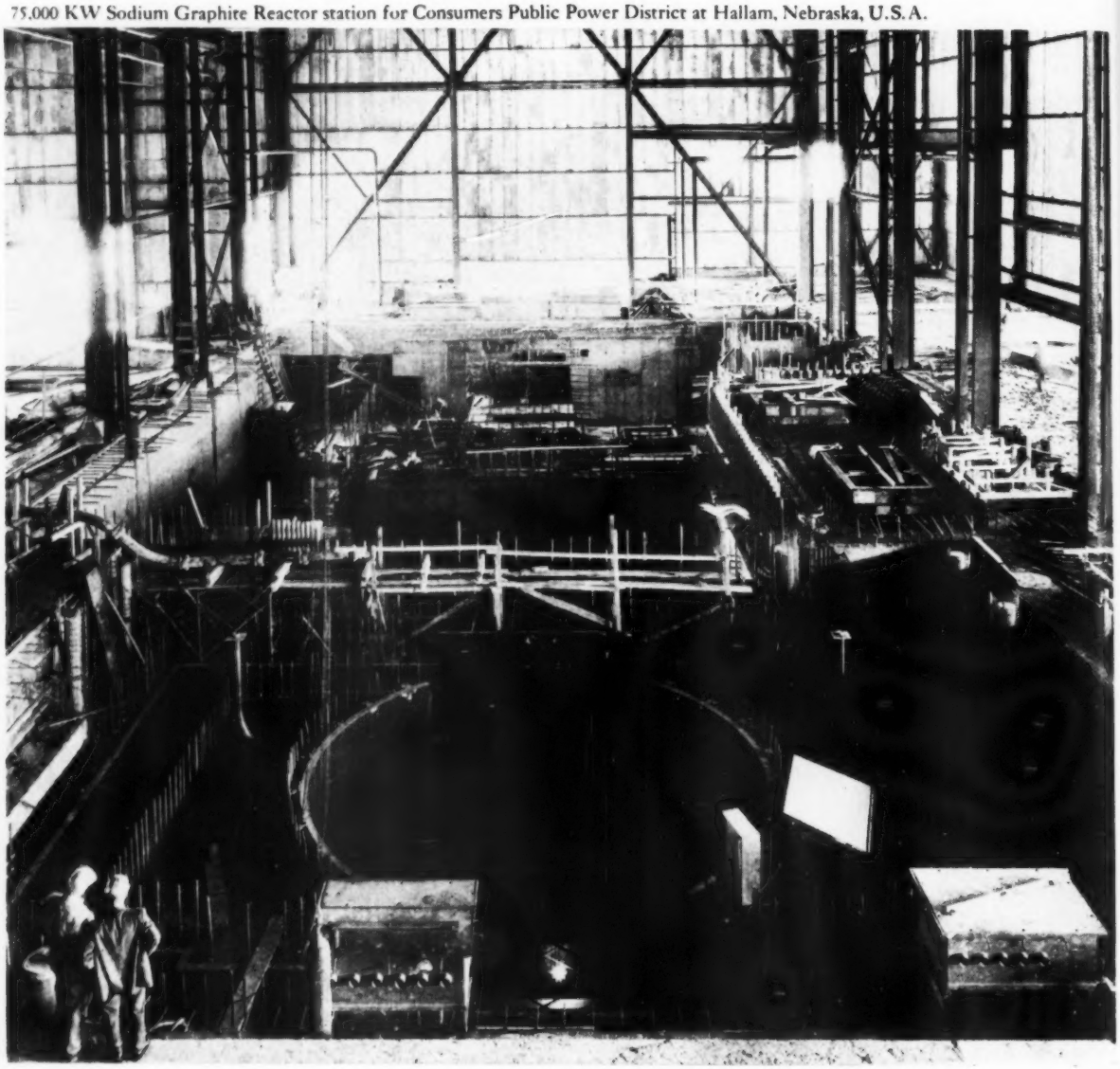
THE STANTON IRONWORKS COMPANY LIMITED NEAR NOTTINGHAM ENGLAND

75,000 KW Sodium Graphite Reactor station for Consumers Public Power District at Hallam, Nebraska, U.S.A.



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The last time we increased our prices was in

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©SQUINCH *does not intend to increase his prices—*
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P6235

managing director

...They always say that the leaves grow greener in the other fellow's garden—but I doubt it.

"Seems to me that being a Managing Director would have its drawbacks. Having to entertain customers when I fancied a yarn with the boys and only seeing a leek when it was dished up in a tureen would drive me fair barmy inside a month.

"Mind you—don't get me wrong. If somebody offered me the job I'd have a shot at it, but deep down I feel that the boss's chair calls for a little more than most of us can give. In the 40 years I've worked for the AW Group I've learned to handle men and make a quick decision. I can talk about steel until the cows come home and I know a few tricks that the professors don't teach . . . but as for being a Managing Director . . . I reckon I'll stick to my own garden after all."

STEEL CASTINGS—with the emphasis on quality

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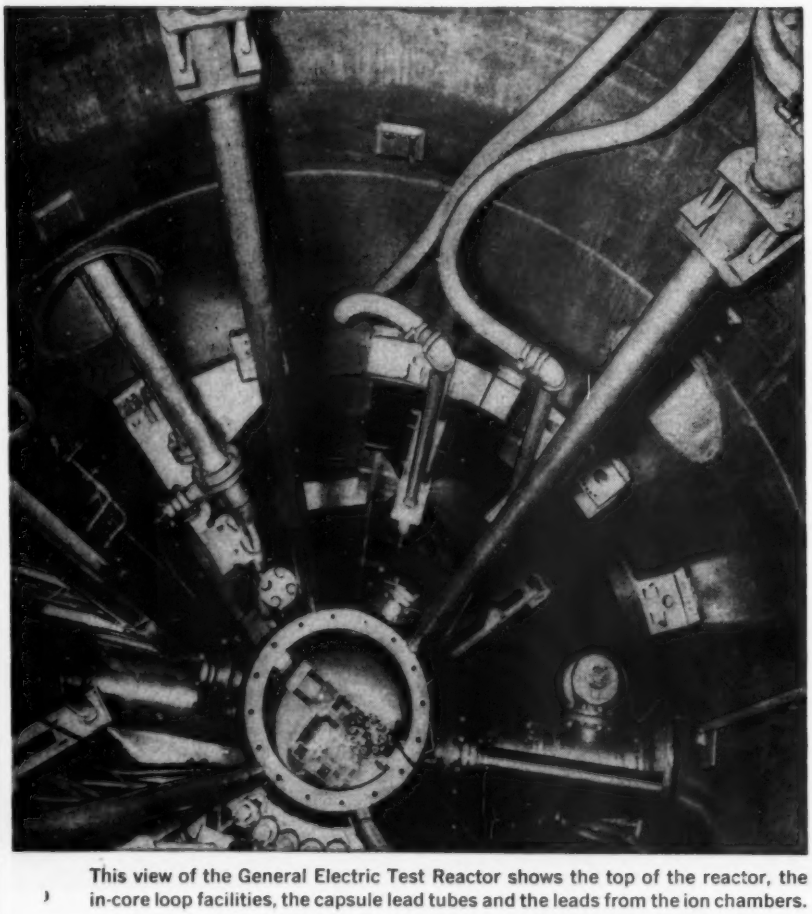
General Electric Invites You To Check Thes Pages For Facts About Irradiation Service And Reliable Nuclear Components



This view of the General Electric Test Reactor shows the top of the reactor, the in-core loop facilities, the capsule lead tubes and the leads from the ion chambers.

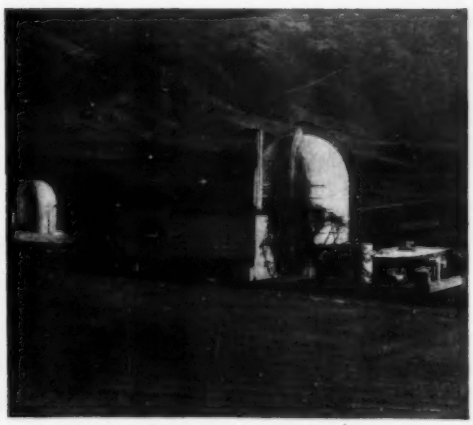
The G-E Test Reactor, a variety of techni services and years of nuclear experience are important parts of General Electric's compl irradiation services in San Jose and Vallec

General Electric's complete nuclear resea facilities in San Jose and Vallecitos, Califor can provide integrated irradiation research development services which range from basic applied nuclear research programs to specific te ing and development operations requiring speci ized experience and equipment. They are availa to private industry and governments through the free world.

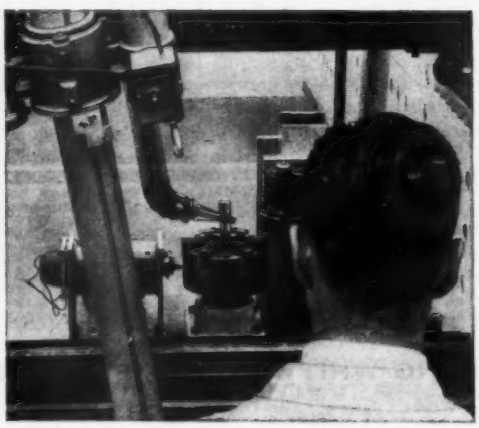
G.E. is staffed and equipped to handle compl research programs from design, procureme and preparation of assemblies for irradiati through irradiation in the General Electric T Reactor (GETR); to post-irradiation exami tion and testing including analysis and reporti A variety of other technical services are availa to meet specialized customer requirements.

Fuel development programs and irradiati studies on materials and components for t advancement of reactor technology can be o tained without the expense of building a react

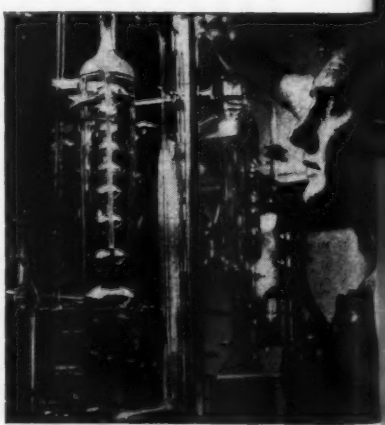
For more information about how General Elect can handle your irradiation research — from st to finish — write for the free bulletin GEA-69



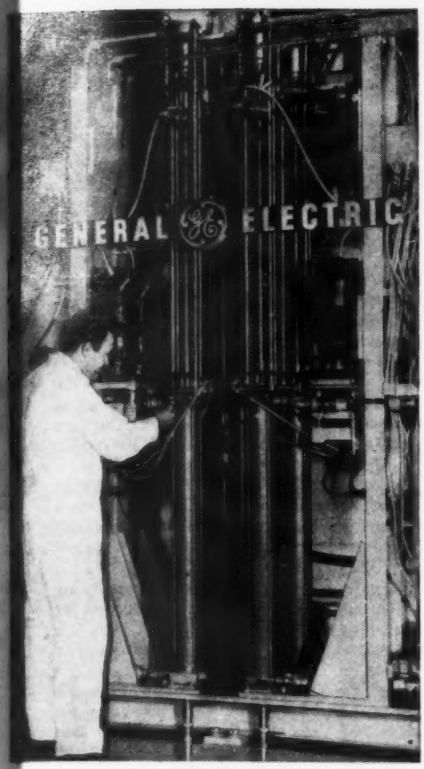
This is the 30,000 thermal kilowatt test reactor built and operated by General Electric. It is designed for irradiation testing of fuels, and other materials.



The G-E hot cell lathe station remotely performs cutting and turning on irradiated materials. A large part of the laboratory is devoted to test cells and supporting operations.



G.E.'s technical services include this nuclea chemistry laboratory, a metallurgy an ceramics lab, a physics lab, a nuclear critic assembly, the GETR and other services.



General Electric experience and dependability are built into every Nuclear Reactor Control Rod Drive

General Electric has developed, designed and built more than 25 types of control rod drive mechanisms for boiling water, pressurized water and sodium cooled nuclear reactors. You are assured of more dependability and greater versatility because of this unmatched experience and these 7 important features:

❶ **Reliable Operation and Easy Maintenance.** G-E drives utilize familiar industrial components so spare parts are not a problem. Moving parts are readily accessible, easy to assemble and maintain.

❷ **Dependable Performance by Thorough Testing.** Control rod drive components have been completely tested and proven in service in operating nuclear reactors.

❸ **Versatile Designs For Every Application.** Combinations of components can be varied to meet requirements for speed, stroke, coast, mounting location, etc. Compact arrangement of G-E drives allows mounting on close centers, providing more effective control and flexibility in core design.

❹ **Accurate Position Indication.** G-E control rod drives can be equipped with various types of position indication systems.

❺ **Quick Delivery Of G-E Standard Drives.** The variety of proven drives designed to meet most application needs save costly design and testing time.

❻ **Automatic Control Available.** G-E drives are designed for automatic control. Complete servo systems and components are available.

❼ **Extensive Test Facilities.** Facilities are available for customers who wish to make additional design tests on control rod drives for use on their own reactors.

For complete information of General Electric's performance-proven line of nuclear reactor control rod drives, send for the free bulletin GEA-6609.

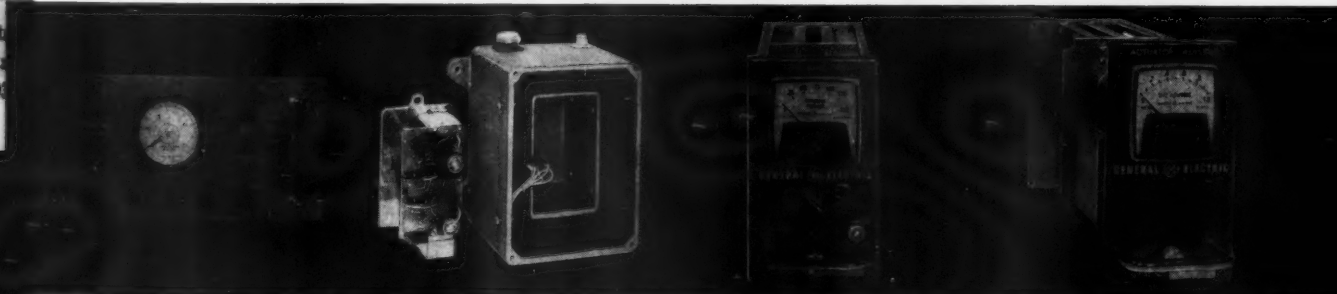
GENERAL ELECTRIC OFFERS A COMPLETE LINE OF NUCLEAR INSTRUMENTS AND A FULL SCOPE OF SYSTEM-DESIGN SERVICES

STABLE MICROMICROAMMETER features fast response and very low zero drift.

HIGH-VOLTAGE POWER SUPPLY—a precision instrument for primary nuclear detectors.

LOG-N PERIOD AMPLIFIER provides accurate neutron flux measurement.

LOG COUNT RATE METER WITH PERIOD gives optimum reactor startup protection.



LINEAR COUNT RATE METER provides direct indication of nuclear pulses.

PREAMPLIFER is a small amplifier for fission or proportional counter pulses.

FLUX AMPLIFIER—for reliable continuous self-testing and automatic substitution.

ACTUATOR AMPLIFIER supplies and controls current to safety magnets to shut down reactor.

Send for free bulletin GEA-7006 on nuclear instruments and system design services.

General Electric leads the way to greater progress in the nuclear field, whether it's for irradiation services, nuclear components or a complete power reactor such as the 180,000 kw Dresden Power Station now in operation near Chicago. For the free bulletins listed above, or for further information about nuclear equipment to meet your needs, write: *International General Electric Co., Dept. 30-11W, 150 East 42nd Street, New York 17, N.Y., U.S.A.*

GENERAL ELECTRIC

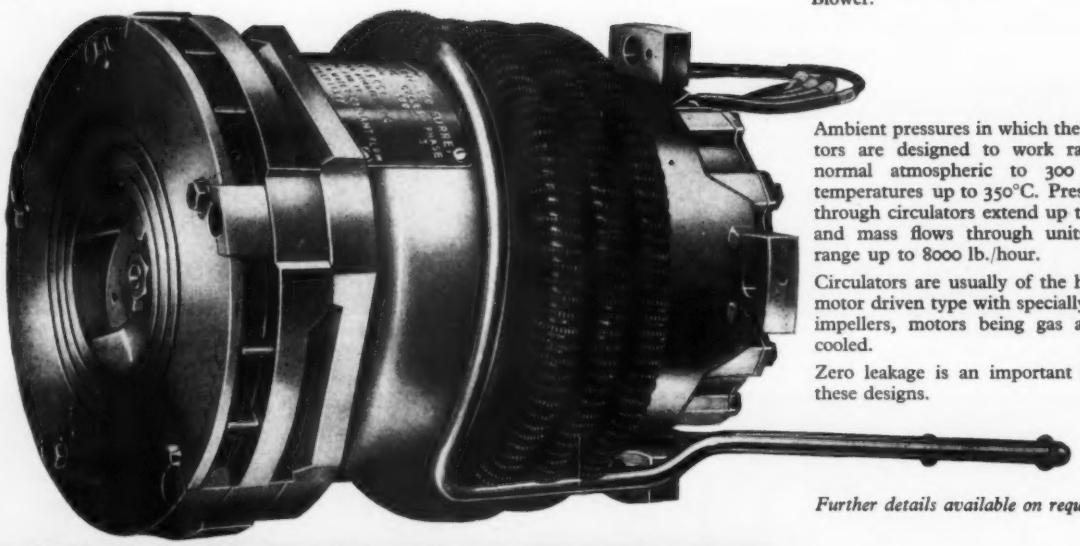
—U.S.A.—

Circle No 43 on reply card for further details

"PLANNAIR" GAS CIRCULATION BLOWERS FOR NUCLEAR PROJECTS

Carbon dioxide circulator for fuel element cluster, here illustrated, provides for reliable and efficient cooling of nuclear reactors. The blower, with its 11,500 r.p.m. motor (200V 400 c/s supply), is sealed within a long pressure vessel at the opposite end to which the nuclear reaction occurs. CO_2 circulates through the tube at 285 p.s.i. A and 95°C. The blower output is 6300 lb./hour at 7·5 p.s.i. pressure differential. A secondary radial impeller gives a cooling gas circuit via a demineralised water heat exchanger coil which keeps the motor operating at below 75°C.

This is but one of several gas circulating blowers which Plannair have designed for various nuclear projects. These include a Leaky Cartridge Test Rig Air-Blower, a Sodium Loop-Nitrogen Circulator, a Helium Circulator, Air Circulators and a Nitrogen Circulator, CO_2 circulator for Fuel Element Cluster Irradiation Test Rig, Burst Fuel Element Test Rig Air-Blower.

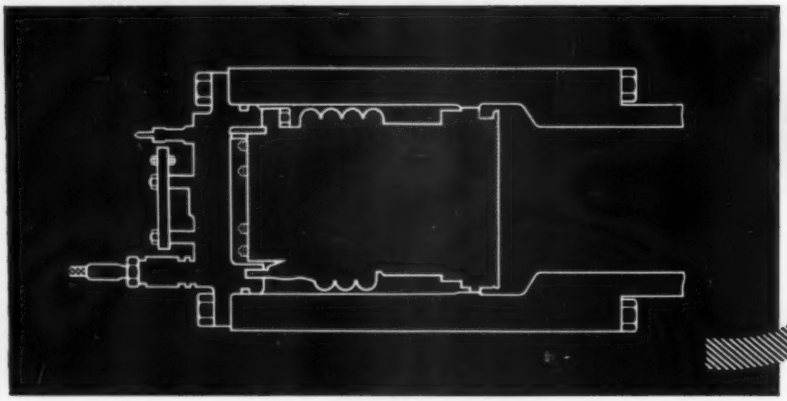


Ambient pressures in which these circulators are designed to work range from normal atmospheric to 300 p.s.i. at temperatures up to 350°C. Pressure rises through circulators extend up to 30 p.s.i. and mass flows through units cover a range up to 8000 lb./hour.

Circulators are usually of the high speed motor driven type with specially designed impellers, motors being gas and liquid cooled.

Zero leakage is an important feature of these designs.

Further details available on request.



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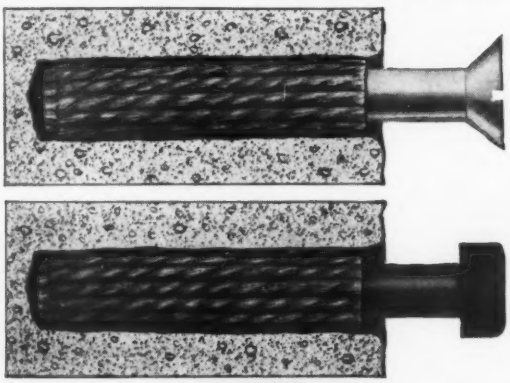
'Rawlplugs are by far the speediest method of screw-fixing in the world'—you've known that for years. But have you noticed how much faster even Rawlplugs are today, with the sensational Rawlplug drills and power tools now available for drilling the holes in all kinds of masonry? It's well worth looking into!



RAWLPLUGS

FOR ALL SCREW SIZES

There's a Rawlplug for every size of screw up to ¾" diameter coach screws, which take a load of 4 tons.

Rawlplugs are the fixing for *neatness* as well as speed and strength—no mess, no damage to surrounding materials, almost invisible in position. Being rotproofed and waterproofed during manufacture, they can be used under all climatic conditions. Screws can be withdrawn and replaced without affecting the efficiency of the Rawlplugs.

Write now for illustrated literature containing full details of Rawlplug Fixing Devices and the many high performance Rawlplug tools (hand, electric and pneumatic).

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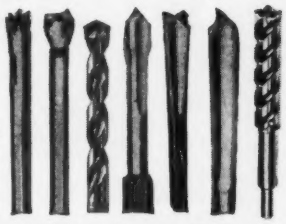
For cutting holes in any material—concrete to glass—Rawlplug tools are the speediest, most efficient and durable in the world. Sizes and types to meet every need—hand, electric or air power. Among hand percussion tools are Rawldrills, Stardrills, Tubular and Wall Boring Tools. For hand or power—Durium, the world's fastest masonry drill, and Durium Glass Drills. Power only—Vibroto, Rawlcrete, Durium Hammer Drills, etc.



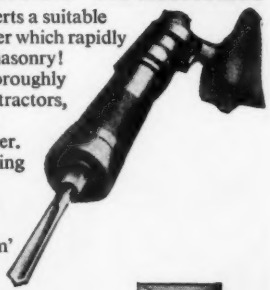
R.P.2 *Two-speed* ELECTRIC DRILL

Keyless Chuck

At the touch of a button you can change the speed of this drill from 1200 r.p.m. to 420 r.p.m. which is the ideal speed for Durium Masonry Drills. Chuck capacity is 5/16". Finger tightening holds the smallest drill in rigid grip which increases with the load yet can be easily released.

RAWLPLUG DRILL HAMMER

This ingenious attachment converts a suitable electric drill into a Power Hammer which rapidly bores holes in even the hardest masonry! A sturdy high-precision tool, thoroughly proved and used by famous Contractors, the Rawlplug Drill Hammer is a magnificent time-and-money saver. Suits any electric drill with working speed up to 2000 r.p.m. and minimum ¼" chuck. Speed—one blow per chuck rev. Weight of blows adjustable 'light', 'medium' and 'heavy'.



Rawlplug VIBROTO Drilling Machine

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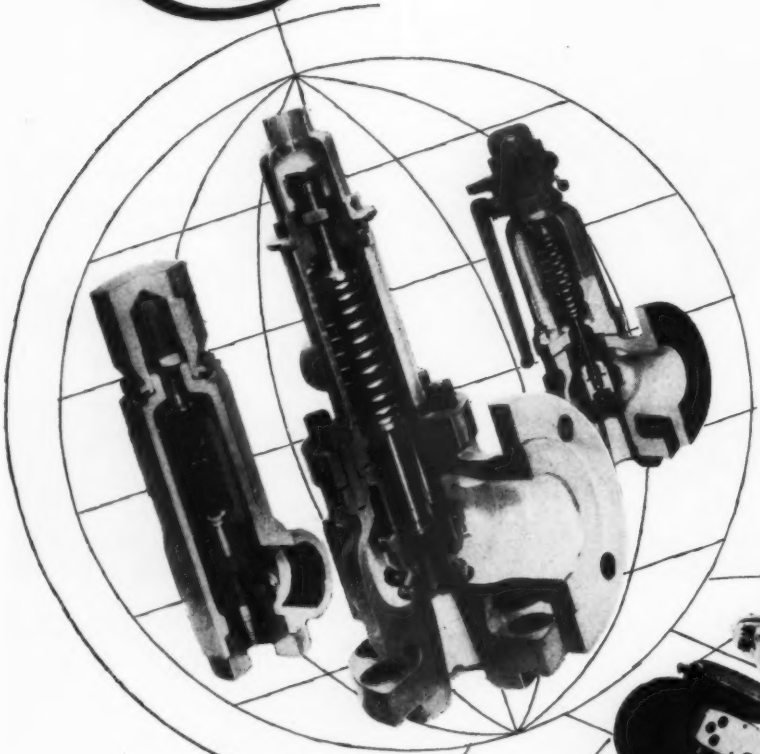

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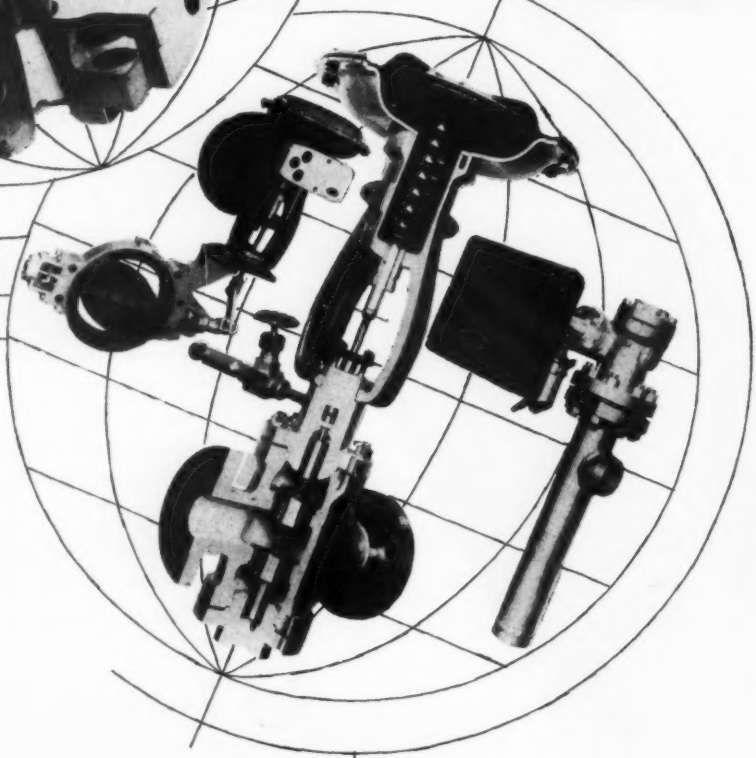

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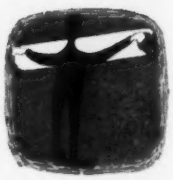

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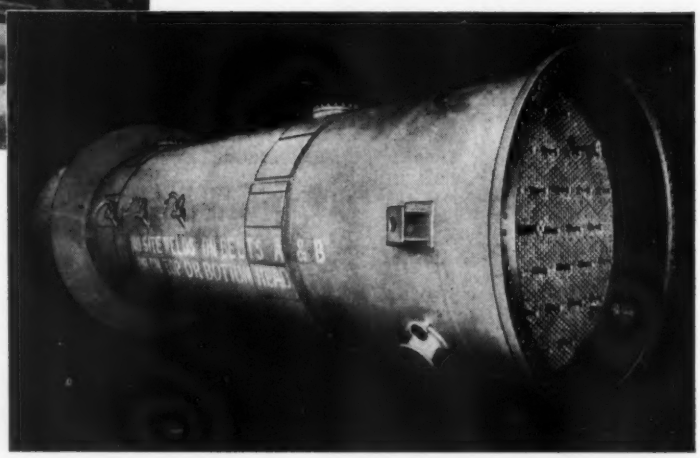

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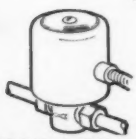

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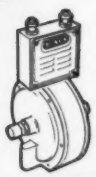

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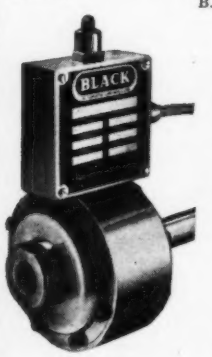

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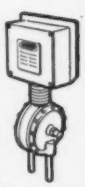

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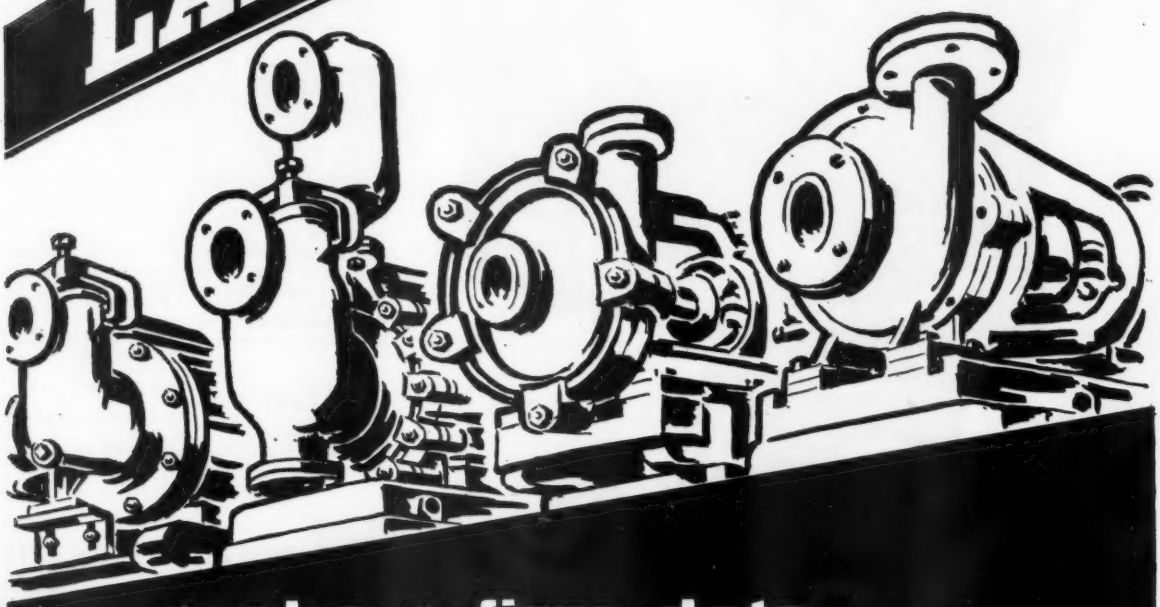

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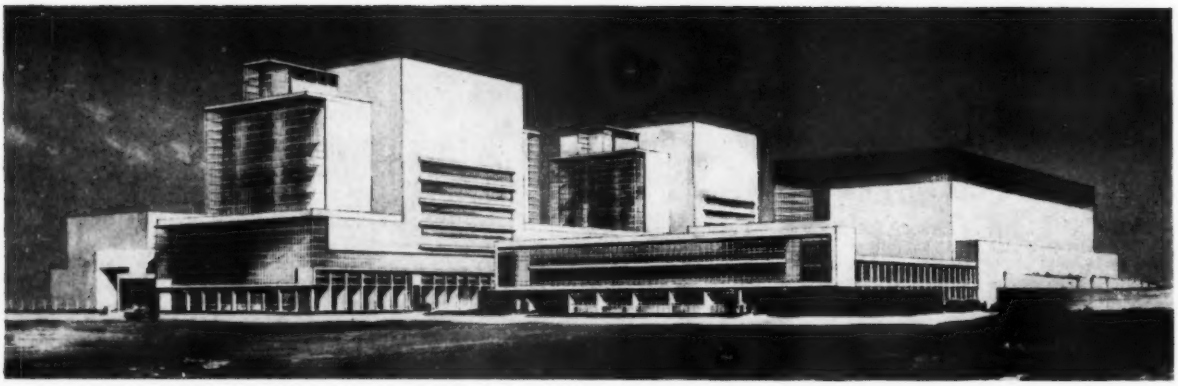
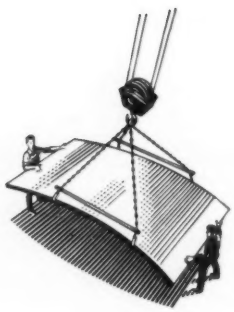


For the Central Electricity Generating Board's new nuclear power station at Dungeness, Whessoe, as a member of the Nuclear Power Group, is building the two 62′ 6″ diameter reactor pressure vessels. The thickness of the steel plate to be used will be up to 4½ inches.

Behind the work Whessoe will carry out at Dungeness is experience gained in the design and construction of 12 reactor pressure vessels at Calder Hall, Chapelcross, Bradwell, Windscale and Latina in Italy.



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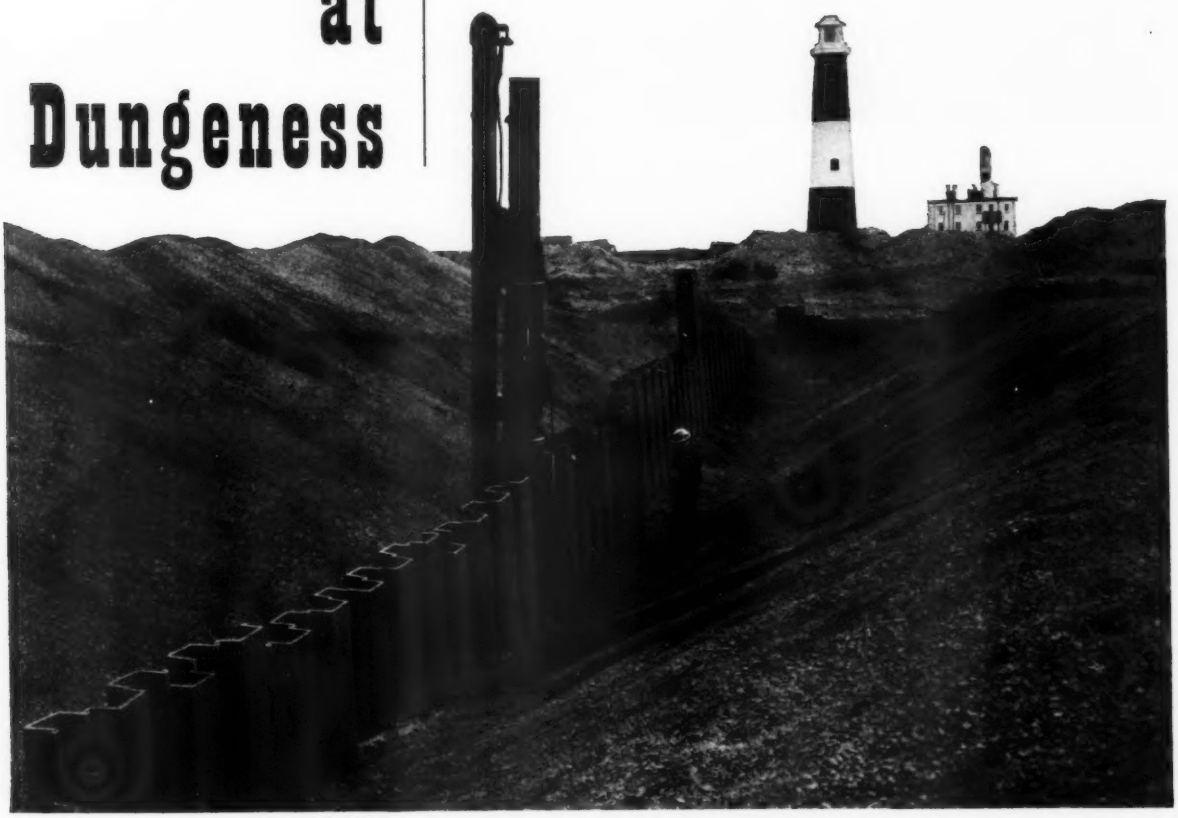

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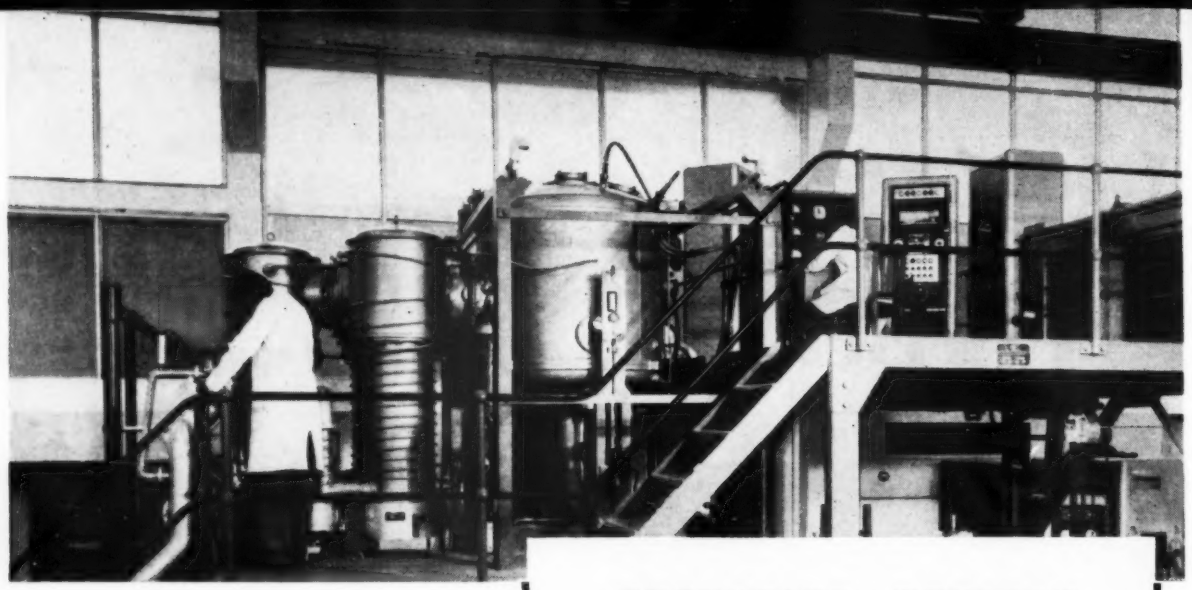

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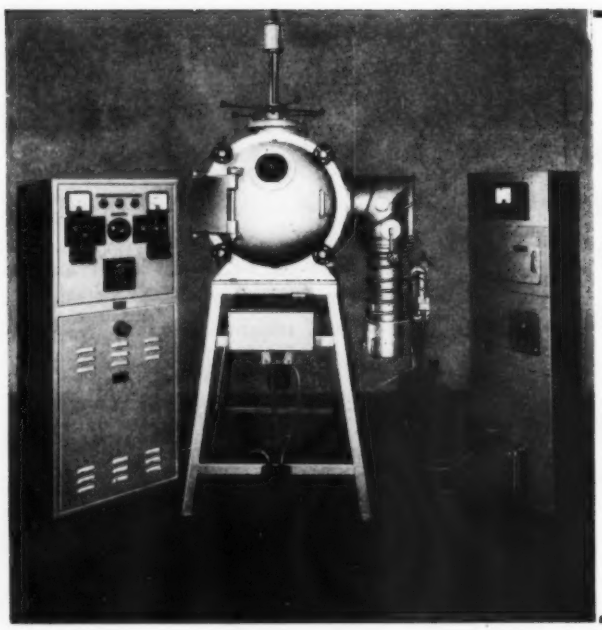

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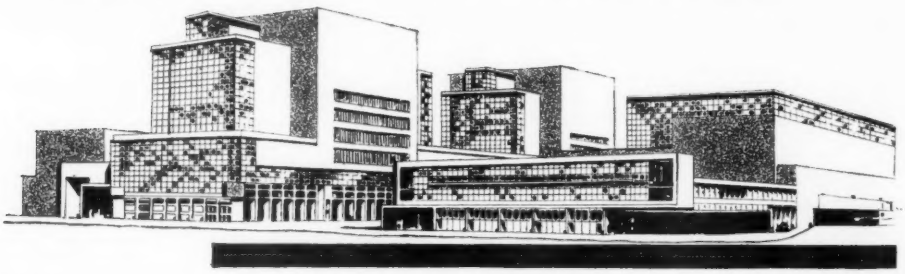

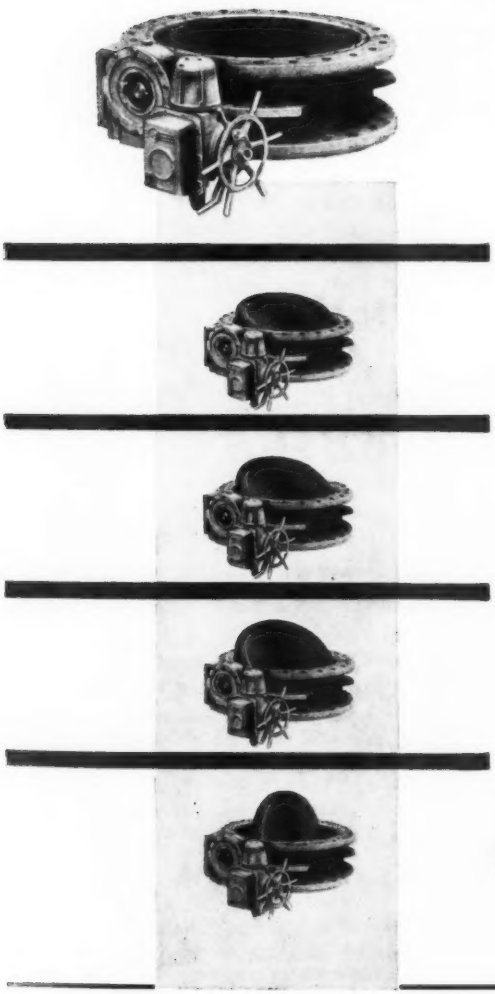

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APRIL 1961 VOLUME 6 NUMBER 60

VIEWPOINTS letters to the Editor

World reactor chart

SIR: On reading through your index and list of world reactors (January, 1961 issue), I found what I thought was an unusual omission. You must have had a very good reason, I suspect, for not listing the proposed French reactor, EDF-3, which is due for completion, I understand in 1965.

However, on the whole, I have found the chart particularly useful and the technical details it contains unusually accurate and detailed. My January issue is in constant use for reference — so much so that it is becoming rather grubby and beginning to show signs of wear. I would like to order another copy and would be grateful if this could be posted on.

W. M. C. WILKINSON

Reading, Berks.

The reason for the omission of EDF-3 *is that it was our policy not to list proposed reactors, however well known, for which no definite letter of intent or contract had been placed. There are some omissions in the index due to it necessarily being compiled at a later date. A few copies of the January issue (containing the World Reactor chart) are still available.—Ed.*

Overseas sales

SIR: I should like, if I may, to take issue with some of the views expressed in your January editorial. You say, quite rightly, that many countries are actively interested in possessing research facilities and that American export dominance is helped by a progressive and dynamic official outlook. You then add that to combat this, the Atomic Energy Authority should carry out a more vigorous policy overseas.

While I would not like to say the Authority is perfect, I should like to ask what more you think the AEA can do? Granted, they could put on more scientific exhibitions overseas to create a possible atmosphere of goodwill and emphasize British technical achievements. This, I think, will have a negligible effect on the hard facts of selling which are the concern of business organizations who themselves are not all that exempt from criticism in their handling of possible sales overseas and in the very definite art of public relations. I am convinced that while credit terms may play a substantial part in determining sales, it is the product, the sales force and the price that are the main factors.

Another point that seems to be overlooked when comparing the USA and the UK is the amount of money the AEA has to spend compared with that available to the USAEC. In your December issue, you quote some figures which make interesting reading. The AEA estimates for 1960–61 are given as about £93 million; for 1961–62 they are about £78 million. Against this, the AEC spent on reactor development alone in 1959–60, £140 million. In fact, the total AEC budget works out at something like ten times that spent by the AEA.

Perhaps, when viewed in this light, the AEA is not doing too badly. There is, of course, room for improvement on both sides with the CEGB's conservative, on-the-fence attitude, not helping matters. But any criticism of the AEA in this particular field must be linked with criticism of the nuclear industry in this country. One could push the other. Instead, one has the impression of pulling in different directions.

B. M. MARTIN

Hadleigh, Essex

Japan's nuclear goal

SIR: I refer to your article 'Japan' published in the January issue (National programmes in 1960, p. 69) and would point out that the Japan Atomic Energy Commission and the Ministry of International Trade proposed, as you say, the installation of 1000 MW by 1970 but in the next ten years, the figure is to be between 6000-8500 MW, slightly higher than your published one. Commenting on this, I would say for your further information that this official programme is a mere goal and one which the Government hopes the electrical and nuclear industries will make the utmost effort to reach. There is no central authority, such as in England, building stations and the programme itself was drafted against a competitive background, i.e., the economics of nuclear power, with the lack of natural energy resources in Japan another important factor. It was felt, in official circles, that it was necessary to diversify the type of energy sources and thus reduce dependence on one or two main imports. Official hopes are that the first ten years from 1960 will be used for research and development and only after 1970 will nuclear power be used on a large scale. This is a good aim but the feeling among certain circles here is that the plan for 1000 MW by 1970 is too optimistic and is a paper programme. It does not really meet the needs of building up a strong domestic nuclear industry as the first phase, if it is to be met, will mean that all the reactors will have to be imported either from England or the United States.

I make these comments to put the programme in perspective as I think it would be misleading to think that a definite building programme has been laid down. Personally, I think that it is not likely that more than one other power reactor, probably a US import, will be built by 1970. More emphasis is likely to be placed on power demonstration and materials testing reactors.

Minato-ku, Tokyo

S. TANIGUCHI

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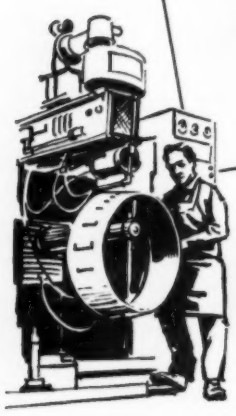

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OPINION

Information and the AEA

WHETHER WE LIKE it or not, our economic system is such that it demands that national research and development, paid for by the British ratepayer, is applied to strengthen our technical ability to compete in overseas markets. It is difficult under the circumstances to decide at what stage free interchange, both internationally and domestically, should stop. Many scientists, including those in the UKAEA, will argue that there should be no such cessation. For those working in industry and in the laboratories of public authorities, this added discipline is an embarrassment. In spite of this, there are the many occasions when workers in the same field find the opportunity to exchange freely ideas, opinions and evaluations—at institutional meetings, at scientific and technical expositions and at international conferences.

Setting aside for the moment the implications of bilateral agreements and international collaboration, the question that arises is : how realistic is the Authority's policy in disseminating information? In its early days, although the distribution of information and the encouragement by contract of research by universities and other institutions or persons were among its terms of reference, freedom of action was considerably hampered by the restrictions enforced upon it by work being done for the military programme. Triggered off possibly by the Eisenhower Act that released to the free world a great volume of once-classified atomic information, and certainly by the first Geneva Conference, the Authority set itself the task of clearing for publication a great number of scientific and technical reports. This move was welcomed by the many firms and establishments outside the privileged few engaged in substantial contract work. But they had little time to enjoy the new freedom: the Authority soon afterwards—in 1956—started clamping down again on the more liberal release of information and a new classification crept in, one that was influenced by commercial implications.

Following a government dictate, the UKAEA's policy was now seriously influenced in its attempt to recover some of its research and development expenditure. With a new cost consciousness, the Authority took the line of withholding from industry commercially potent information unless industry was prepared to either pay for it in the form of access agreements or in the form of licence agreements, plus royalty payments. This attitude is not universally accepted, however, for many people hold the view that the benefits of research and development, paid for out of public funds, should be passed on to British industry. Export potential is thereby increased and the nation profits anyway.

Nevertheless, any serious attempt by responsible public administration to offset large expenditure is not to be condemned out of hand: it is praiseworthy provided it relates realistically to industry's ability to pay. The electricity boards and the consortia, for instance, were not prepared to agree to pay royalties on the first four nuclear power stations, a sum amounting to some £20 million by mid-1965. They settled for the lump sum equivalent of £2.5 million for each of the two stations to be completed between 1963 and 1965. The Select Committee of 1959 thought that increase of royalty payments was short sighted and detrimental to the commercial prospects of the domestic nuclear power industry. A more recent view in Parliament was that by driving a hard bargain on the use of patents the Authority would deter industrial exploitation anyway.

It is therefore suggested that this new commercial outlook is in some ways unrealistic. While there may be no argument on the really big issues of doing business in fuel elements, graphite and isotopes, is it not pettifogging to hold up information on relatively smaller developments for the sake of possible payment? Taking a look at the activities of the National Research Development Corporation over the last year—with 81 licence and option agreements negotiated, and an accumulative total of 456 in force—the produced annual revenue of £259,000 was only slightly in excess of the corporation's administrative expenses. As a comparison, it would be interesting to see details of the AEA's turnover on licence agreements and royalties, together with administrative costs.

The Authority should look again at its commercial policy and decide whether or not it should take a more liberal view on the release of information on many more categories of applied research than it does at present. One attitude it could consider is that taken by most research associations in this country and by, for example, the Canadian atomic energy authorities, who, after a one-year period, release information for general use.

Industry is reluctant to pay through the nose for ideas and services, particularly when they stem from government research organizations. Similar U.K. research establishments with a long and successful association with industry expect only token payment for results, and in some cases pertinent information changes hands freely. Left as it is, what situation do we face? Whilst the consortia benefit to some extent by collaborative arrangements, and some good comes from access agreements, firms outside the patronage of the Authority are kept in the dark. It is a fact that in some instances information withheld in the UK can be obtained from North American authorities and other operators with little trouble. It would be interesting to discover how much of the information exchanged under bilateral agreements and through international research projects, in many cases denied to individuals in this country, reaches these same people by devious means.

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WORLDVIEW

the month in atomic energy

EUROPE

UK industry disagrees about Foratom

London The first exploratory meeting to discuss whether the UK should join Foratom, the European grouping of national nuclear forums, and set up its own Atomic Forum was not completed and no decisions were taken. A further meeting will be held on April 17.

The meeting was private and convened on March 3 by the Federation of British Industries. Present, according to the FBI, were people representing every aspect of the peaceful uses of nuclear energy. The FBI added: 'It was an exploratory meeting and a further meeting will be held'. About 70 people attended and *Nuclear Power* understands that a small working party is to go more thoroughly into the matter.

Industry's attitude is mixed and confirms the impression that there is a considerable division of opinion on these two subjects. One of the consortia did not even accept the invitation to be represented and there is a widespread feeling that the existing channels of communication eg. the Board of Trade nuclear energy committee, The Nuclear Energy Trade Associations' Conference (NETAC), and, more important, direct contact betwen the most highly placed members of the groups, and the government policy makers are sufficient. As far as overseas contact is concerned, the large groups have links with companies in almost every potential market.

Against this is argued that for the smaller companies, a UK Forum would provide a meeting ground which would be rather freer than those existing at the moment. Also not joining Foratom would mean that another opportunity to work more closely with Europe would have been lost. If the UK were the only nation not to join Foratom, the feeling abroad that atomic energy in Britain was a national programme and controlled by the government, would be strengthened.

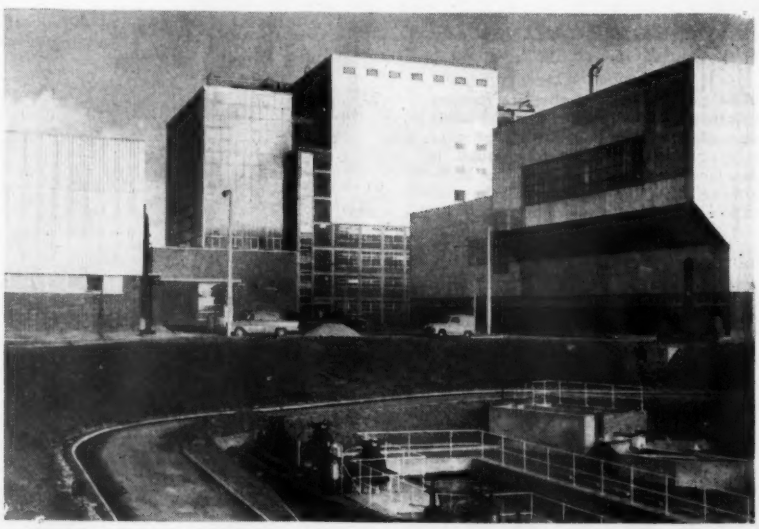
The Atomic Energy Authority, who stress that the decisions to join Foratom and set up a UK Atomic Forum are purely matters for British industry, say that if industry did agree to join Foratom, the AEA would support this.

Discussions on a new association for the nuclear industry have been going on quietly for some time (see Gracchus, January 1961, p 92) and this meeting was the latest development. Late in 1960, for instance, the Grand Council of the FBI were understood to have approved unanimously the idea put forward to them of such a British association. If a sufficient body of opinion seems in favour, the FBI might consider setting up a Forum and then withdrawing, leaving it to run itself, but would prefer to see a few prominent and acceptable people in the industry take the necessary steps.

Meanwhile, Foratom, the Forum Atomique Européen, is proceeding steadily towards its first international congress on the peaceful uses of atomic energy to be held in Paris next year (see *Worldview*, October 1960, p 70). The six Euratom-nation founder members announced when the new grouping was established in July last year, that they would accept for membership, representative nuclear associations from other than Euratom countries. In fact, at that time, Foratom accepted without dissent, the application for membership from Switzerland's Association, Sussie pour l'Energie Atomique.

• **United Kingdom** The newly formed Nuclear Energy Standards Committee of the Britsh Standards Institution held its first meeting recently. Purpose of the committee is to deal with high level policy matters and direct other nuclear technical committees' work.

• **United Kingdom** The 10 kWt Neutron Source Thermal Reactor, NESTOR, has been put into operation at Winfrith Heath. It will act as a neutron source for sub-critical assemblies.

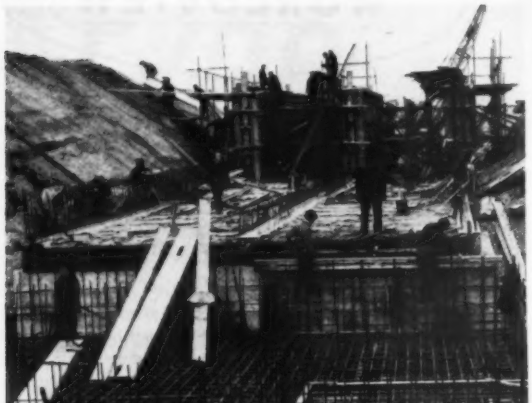


The 300 MW Bradwell nuclear power station is due for completion this year and this latest picture shows a general view of the No. 1 reactor with the pumphouse at left and at right, part of the turbine house.

WORLDVIEW

Dungeness

Recent pictures show work in progress at the site of the Dungeness nuclear power station, which is described in full in this issue



The excavation and foundations for No 2 reactor, looking east. The main batching tower can be seen in the left background and the rising structure for the 'J' crane in the centre

▼

View on the west of the site looking towards Lydd Airport shows the erection of the 'J' crane; the girder construction in the right foreground is the Goliath support tower. The background shows in the centre the site canteen and to the right the main TNPG offices

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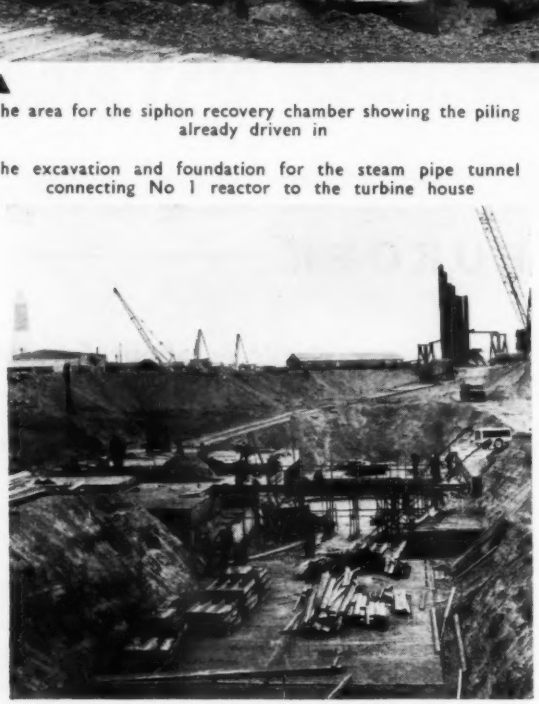
The area for the siphon recovery chamber showing the piling already driven in

◀ The excavation and foundation for the steam pipe tunnel connecting No 1 reactor to the turbine house



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A view looking east towards the lighthouses of the excavation and foundation work for the turbine house. The small brick building in the left background is the de-watering pumphouse. The piling in the right background is in the C.W. pump area

On the east of the site, this view shows, in the bottom left foreground, the John Thompson Welding School and workshop. In the centre are the jigs for fabrication of the pressure vessel and to the right the unfinished structure for the boiler fabrication shop. In the far left-hand corner the aggregate dump for concrete making can be seen

▼

WORLDVIEW

IAEA makes reactor agreement with Norway

Vienna The IAEA is to take part with Norway in a scientific research programme in reactor physics using the Norwegian zero-power reactor, NORA, which is now nearing completion. This was approved by the IAEA Board of Governors at its first 1961 series of meetings which ended recently.

Other points agreed to included a trilateral contract (IAEA-Norway-USA) under which the USAEC will make available for use in the joint programme, a core, enriched to 3% in U-235, which was used in development work for the *N S Savannah*. Two core loadings are being provided by Norway, one consisting of natural uranium and the other enriched to 1·7% in U-235. It will be possible to conduct studies during the three year programme on three core loading of varying enrichments.

The Board also decided to establish an inter-governmental committee of representatives of 14 countries to draft an international convention on civil liability for nuclear damage. The basis for the Committee's work will be a draft convention drawn up by a panel of experts appointed by the Director General and the comments on this draft received from member governments.

The IAEA agreed to send 31 experts to Argentina, Brazil, Ceylon, Greece, Iceland, Indonesia, Israel, Korea, Mexico, Morocco, Pakistan, the Philippines, Sudan, Thailand, Turkey and Yugoslavia to help the nuclear developments.

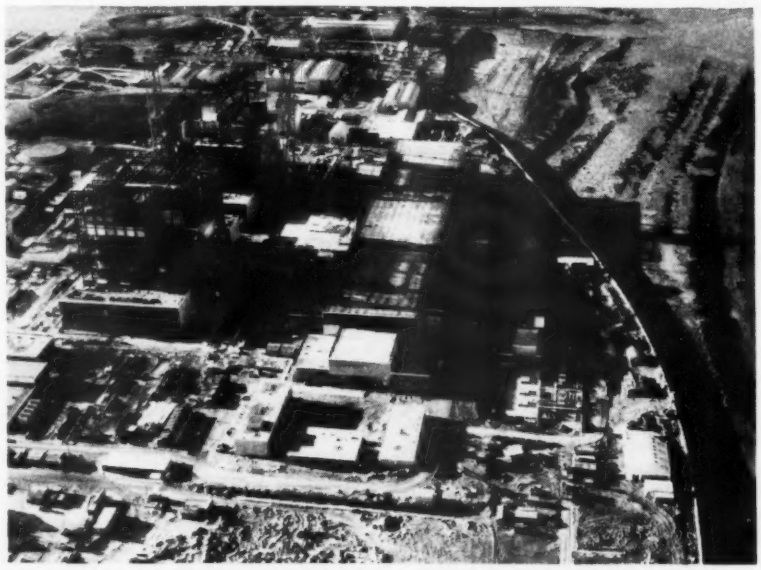
Under another agreement, the IAEA is to undertake research on the effects of radioactivity in the sea. This agreement was signed between the Agency, the Government of Monaco and the Oceanographic Institute in Monaco.

W. Germans work on fission products

Mainz Work to identify short-lived primary fission products created in the nuclear fission process which have not yet been detected, will be carried out at the Institute for Inorganic and Nuclear Chemistry, Johannes Gutenberg University.

Professor Fritz Strassman, the co-discoverer of nuclear fission, has stated that by means of high intensity pulses of neutron energy of milli-seconds duration, it might be possible to identify and measure these fast-decaying products and thereby change the present-day concept of the structure of a number of elements.

Professor Strassman indicated that this work would be carried out by using a 30 MWt TRIGA Mark II reactor for which a contract had been signed with General Atomic of the US. The reactor is scheduled for 1962 operation.



At Hinkley Point nuclear power station both pressure vessels are now fully installed, all 12 heat exchangers are in position and construction of the pile cap roofs is in progress on both reactor buildings. This view shows the two reactors (left) and the 700 ft long turbine hall (right)

• **France** According to a decree in the French Official Gazette, the statutes of the Societe d'Energie Nucleaire Franco-Belge des Ardennes have been approved. The company is to operate the Chooz PWR station to be built shortly.

• **France** The heavy water pilot plant at Toulouse to test production of heavy water with natural gas is to close down shortly. French needs were not sufficient to justify a commercial plant yet, according to official sources.

Euratom—German marine propulsion contract

Hamburgh A major step towards co-ordinating European efforts in marine propulsion was taken recently when a contract was signed between Euratom and two German companies on a marine propulsion project.

This provides for Euratom participation in the project currently being carried out by the Hamburgh GKSS company (Company for the Application of Nuclear Energy in Shipbuilding and Navigation). GKSS has a contract with Interatom for an OMR propulsion unit on which design work and tests have now been carried out. Euratom's participation is retroactive and will cover the whole design phase for the OMR up to and including the completing of working designs which are expected to be ready by end–1961. Euratom's 40% participation will cost 4·48 million D. marks.

UK nuclear society dinner

London While the long-term outlook for nuclear power remained as favourable as ever there seemed also to be now a number of shorter-term factors which were improving its prospects. This point was made by Dr Charles Sykes, chairman and managing director of Thomas Firth & John Brown Ltd at the 13th annual dinner of the Nuclear Engineering Society.

Others present included: Sir Leonard Owen, AEA Member for Production, the president of the society, who referred to the recent AEA organizational changes. He stressed the importance of co-operative and friendly relations between the people, not only within a group, but in different groups.

• **United Kingdom** Some 100 employees at the Poole factory of Nuclear Graphite Limited have been declared redundant. The firm has completed an order for Berkley nuclear power station and is waiting the start of work on the Dungeness station.

• **W. Germany** Rheinische-Westfaelisches Elektrizitaetswerk (RWE) is studying the economics of a 250-300 MW plant and a report is expected in the first half of this year, says RWE's annual report.

WORLDVIEW

Second Halden fuel charge ready

Stockholm The first part of the second fuel element charge for the Halden boiling heavy water reactor is now ready for delivery from AB Atomenergi's fuel element plant here. This is about one third of the whole order, amounting to slightly over 1½ tons of zircaloy clad uranium oxide enriched to 1·5% U-235. After neutron physical measurements in the RO reactor, the elements will be transported to Norway in a special trailer. The delivery will be completed during the spring.

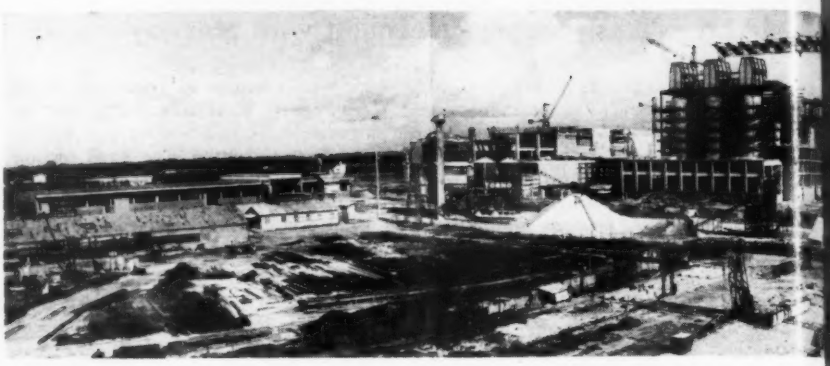
E. German isotope centre

Berlin An Isotope Distribution Centre has been set up in East Germany under a recently published regulation in the country's Official Gazette. The centre is located at the Nuclear Research Institute, Dresden-Rossendorf. It will distribute radioactive preparations, especially radium, uranium and thorium and their compounds.

• **Holland** Talks have been held with the USA on a proposed visit to Rotterdam by the *N S Savannah*. The *Savannah* makes her maiden voyage this year and will call at European ports.

• **Italy** Italian plans include several new reactors and nuclear marine projects, the Minister for Industry said when he opened the National Committee for Nuclear Energy's computing centre at Bologna.

• **Norway** An agreement providing for the exchange, amongst others, of scientific and technical personnel and information has been signed with the USSR.



Progress at Latina nuclear power station is clearly shown here. To the left is the administration block, centre, the turbine house and right, the reactor whose rated output is 200 MW. The station is a joint enterprise between AGIP Nucleare of San Donato Milanese, near Milan, and the Nuclear Power Plant Company Ltd.

UK nuclear ship budget slashed

London Official indecision on the development of marine reactors was revealed in the Ministry of Transport Estimates for 1961-62 which provide for only a token sum of £10 for preliminary expenditure on the design and development of such a reactor. This compares with £250,000 put aside last year. The Ministry points out that this token sum could later be changed when the Government decides on whether to build a nuclear-powered ship. A decision is likely soon.

The AEA's estimates are for £78,320,000, a drop of some £15 million compared with last year's figures. (see *Gracchus*, this issue.) The UK contribution to the DRAGON project will rise to £2,083,000 against £1,228,000 last year and advance payments for uranium to £8,506,000 from £250,000.

Earlier, the Minister of Transport, Mr Ernest Marples, refused to confirm or deny reports that the expert committee examining tenders for a reactor for Britain's first nuclear ship had recommended that the project be postponed. He said that he personally had not received their report and it had not been presented to him.

The Minister told the House of Commons that the committee assessing the tenders for a reactor and propulsion machinery suitable for a 65,000 ton tanker had practically completed its work and would shortly meet to draw up its report.

• **W. Germany** Current for the grid will be supplied ' probably at the end of March ' by the 15 MW Kahl BWR station.

• **W. Germany** A Nuclear Affairs Bureau has been set up by the Schleswig-Holstein Ministry of Economics and Transport.

OVERSEAS

SL-1 films show core damage

Washington Severe damage to the core of the 3 MW SL-1 reactor has been revealed by motion pictures of the interior of the reactor vessel, says the AEC. An accident occurred at the SL-1 in January resulting in the death of three men (see *Worldview*, February and interim report, March p 96).

The films, taken through five 24 in long, 6 in diameter nozzles penetrating the head of the reactor, showed bending, wrenching and expansion of the core. They also disclosed the presence of bubbles —evidence that there is water in the core. In addition, the films showed that four of the five control rod blades appeared to be partially or fully in the core and that one appeared to be entirely out of the core.

Radiation readings taken two feet about the reactor vessel indicated a level of about 650 roentgens per hour. Readings in the reactor room since the accident have ranged from 500 to 1000 roentgens.

Another report on the accident, submitted to President Meany of the AFL-CIO (American Federation of Labour-Congress of Industrial Organization), questions the design of the reactor and concludes that in the future, power reactors should approach population centres only to the extent that absolute containment of missiles and fission products can be guaranteed in the event of an accident.

• **Australia** The Government has withdrawn its offer of cash rewards to discoverers of uranium deposits.

• **India** Building of a nuclear power station in the Delhi area is being considered by the Government, the Indian Parliament was told recently.

• **Japan** A seven-man delegation recently visted Germany during a study tour on European energy policies.

• **United States** US General Electric is to provide a 3 MWt open pool reactor for Rhode Island.

• **United States** A bill which would authorize the spending of $500,000 on a study of the feasibility of building nuclear powered icebreakers has been introduced into Congress.

U.S. Congressional hearings on atomic energy

Washington The decision to abandon the TURRET high temperature gas-cooled reactor experiment planned for construction at Los Almos was not that the idea did not have technical merit, but because construction seemed premature, the Joint Congressional Committee on Atomic Energy was told recently by AEC Commissioner Robert E. Wilson. He was speaking at public hearings on the development, growth and state of the atomic energy industry held from February 21-March 2.

Mr Wilson said that though TURRET had been dropped, basic information required on fuel behaviour and control of highly contaminated helium at high temperatures could and would be developed in gas-cooled loops in other reactors. This information could then be translated into an engineering experiment best designed to demonstrate the solution to the technical problems.

Since the TURRET experiment became part of the Los Alamos Scientific Laboratory's programme in December, 1959, about $450,000 (£160,000) has been spent. Construction was to have begun in March and the reactor was expected to be ready in a year.

The hearings before the Joint Committee were held under Section 202 of the Atomic Energy Act of 1954, requiring hearings to be held within the first 60 days of each session of Congress. Particular subjects considered were: materials technology problems in the nuclear power industry; findings and recommendations of the McKinney Report; industrial comments on regulatory programmes and industrial aspects of the nuclear space programme.

On the civilian power reactor programme, Mr Wilson stated that in the field of organic cooled reactors, new fuel elements had been developed. These should make it possible for OMR to take its place with the water systems in helping to meet the AEC objective of competitive nuclear power in high fuel cost areas by 1968.

There had been several encouraging factors in gas-cooled reactor developments. Promising technical reports on the development of a very dense graphite as a relatively impermeable container for fuels caused the contractor for the High Temperature Gas-Cooled Reactor project to change the design specifications of the first core to unclad rather than metal-clad elements. Indications were for improvements in neutron economy and temperature potential.

Fuel element development activities, principally applicable in the gas-cooled area, had led to the production of impermeably coated particles of fuel material dispersed in a ceramic matrix. 'Fuel of this type may prove useful in the HTGR reactor and it has also opened up the possibility of pebble bed reactors which have a potential advantage of high thermal efficiency and simplified reactor design,' Mr Wilson added.

On the molten salt reactor concept, substantial progress had been made. Experimental work found containment and moderator materials which proved compatible with the molten salt mixture in long tests under operating conditions. This work also resulted in the development of a salt mixture that had stability, low viscosity and a high boiling point.

Discussing radioisotopes, Mr Wilson emphasized the use of radiation to help preserve food. Two more irradiators for the food programme were to be built. One would be located in California to provide a radiation source for proposed research on fruit and another in Seattle to support proposed experimental work on flounder (a small flat fish) and crab.

Other witnesses included Mr R. W. Dayton, assistant technical director, Batelle Memorial Institute, who thought that an expansion of the materials research propramme, by some 50% in size, appeared desirable. The solution to the problems of nuclear materials, especially the cost of fuel, were of critical importance and outranked other reactor problems.

Describing work on the Aqueous Homogeneous Thorium Breeder Reactor, the director of Oak Ridge National Laboratory, Alvin M. Weinberg, said studies showed that the fuel cycle cost of the aqueous system should be about 1 mill per kWh; moreover, the fuel cycle cost was relatively independent of the raw material cost. Two years of operating experience with HRE-2 had shown that such reactors could run reliably for long periods. On January 5, 1961, HRE-2 achieved the full design power of 5 MW; the reactor was chemically stable and the problem of fuel stability which over the past two years had plagued Oak Ridge Laboratory had been solved.

The remaining technical problem which stood between the building of a small-scale aqueous breeder was the thoria blanket. As a result of success in circulating, for the first time inside a reactor, a slurry of thoria in heavy water (the loop operated without incident for 2200 hours), he was confident the blanket problem could be solved. Mr Weinberg added: 'My belief is that unless we hit a streak of very bad luck in the blanket development or in the maintenance problem we could be ready to start designing a small aqueous homogeneous breeder in about two years'.

Points from other witnesses' statements included:

A statement from Lauchlin M. Currie, Babcock & Wilcox Co., which pointed out that as the gap in knowledge between the US and other countries in propulsion plants was decreasing and since the construction cost gap would increase between the US and these countries, development and construction of additional nuclear marine plant should be encouraged by the US with assistance provided to shipbuilders and operators. A dominant factor in costs of nuclear fuel was the uncertain cost of fuel reprocessing and close co-operation between the Government and chemical industry was needed.

A recommendation by Leo Goodman, Atomic Energy Adviser to the United Atomic Workers, that the AEC, the UK AEA and Euratom join together to produce nuclear power stations. Mr Goodman proposed a goal of achieving nuclear power in 1000 locations as soon as possible.

A further recommendation by Dr Lyman R. Fink, of the US General Electric Co., for continuing the programme for developing fuel and material technology and a need to bring up-to-date, the pricing on enriched uranium.

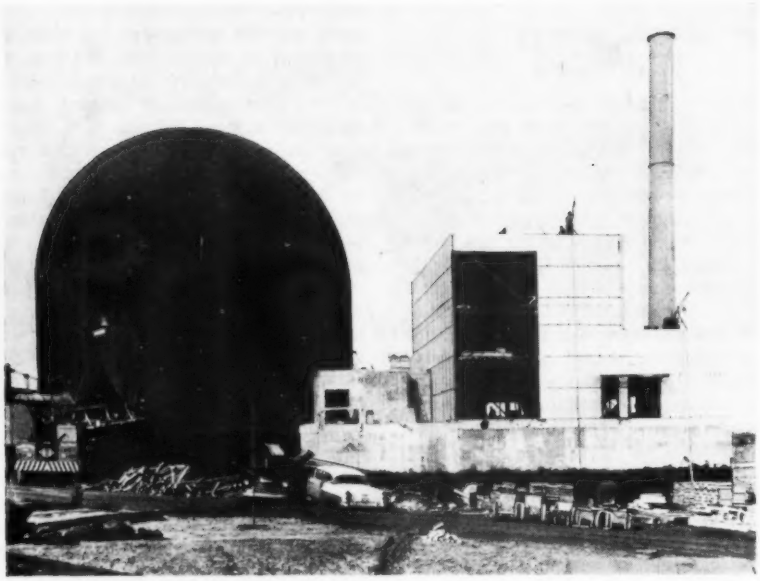
Soviet PWR station nears completion

Moscow Equipment for the first turbine for the 420 MW Novo-Voronezh PWR station by the River Don has been delivered. The crane to be used to assemble the reactor pressure vessel—13 ft across and 40 ft high—is being brought into operation. The first section of the station, consisting of three 70 MW turbines, goes into service next year.

Another Idaho incident

Washington The USAEC has confirmed that a 'chain reaction of a low level' occurred in the chemical processing plant at the National Reactor Testing Station at Idaho Falls. It resulted in an increase in the level of radiation inside the plant and 140 employees were evacuated for nearly five hours. The incident took place on January 26.

- **Australia** Radioisotopes are being used to trace silt movements in Newcastle harbour.
- **Israel** The 24 MW reactor being built near Beersheba has been under construction for the past 18 months and is expected to be completed in three to four years, says Barclays Bank DCO.
- **Pakistan** A radioisotope centre has been opened at the Jinnah Central Hospital, Karachi.
- **USSR** The electricity networks of Finland and the USSR have been connected and Finland will now import power from the Soviet Union.



The Piqua (Ohio) organic moderated and cooled reactor is to be completed this summer. The 11·4 MW reactor will be placed in the dome-shaped housing and the building at right will contain process equipment, a control room and offices. The plant is being built by Atomics International as part of the AEC's power demonstration programme.

Aircraft engine flight tests soon

New York A high performance nuclear turbojet power plant will be available for flight testing in the mid-1960's according to US General Electric. The company has started and brought two modified turbojet engines up to normal operating performance on nuclear power alone.

This test was the third and last in a series of Heat Transfer Reactor Experiments (HTRE-3) conducted to verify aircraft nuclear propulsion design factors and operating characteristics. The reactor core for this experiment used concentric ring metallic fuel elements and a solid moderator material. It is capable of operating at 2000 F. The assembly has now been shut down to prepare for test of more advanced reactors.

The first test (HTRE-1) took place in 1956 when a turbojet engine operated exclusively on heat supplied from a reactor. The second experiment was designed to test new material proposed for use in building future aircraft propulsion plants. It is a modification of HTRE-1 and the core for HTRE-2 contains a test hole into which various reactor materials can be inserted for testing. This is still in operation.

GE is now designing a high-performance nuclear turbojet plant for ground and flight testing under contract to the US Air Force and the AEC.

AEC abandons plans for small PWR

Washington After considering proposals submitted to an invitation to build a small nuclear power plant with a PWR, the AEC has decided not to proceed any further. A statement said that the proposals were unacceptable and had been rejected. This was because of increased costs due to the remote siting of the plant which when viewed in the light of recent studies, indicated that the economic potential for the project in the reasonably near future did not warrant proceeding with the project for a 15–20 MW plant at this time.

• **Australia** Within four to five years, a start could be made on designing and building a high temperature reactor using beryllium fuel elements said the chairman of the AAEC at Launceston.

• **Formosa** Uranium fuel for the National Tsing Hua University's 1 MWt US General Electric pool type reactor has arrived.

• **United States** Conceptual design of an OMR system as the first phase of a proposed 50 MWt prototype power plant is being conducted for the AEC by Atomics International.

• **Australia** A new uranium deposit has been located in Rum Jungle. It is described as comparatively large.

• **India** A broad agreement for co-operation in the nuclear field, covering both natural uranium and fast reactors is expected to be signed with the Soviet Union.

• **Japan** The Japanese AEC has approved a 20 year programme for the peaceful development of atomic energy. Under this, 1000 MW will be built by 1970.

• **Thailand** Construction of a research reactor is expected to begin soon. It will be similar to the University of Michigan's Ford nuclear reactor.

India can build small power stations

New Delhi India now has the ability to construct small-sized nuclear power stations, Dr H. J. Bhabha, the chairman of the Atomic Energy Commission said here recently. He pointed out that the Commission was not yet in a position to undertake large power projects but did not envisage that, in the Fourth Year Plan, it would be necessary to call for world tenders.

The chairman repeated India's objections to certain safeguards proposed in the statute of the International Atomic Energy Agency and said acceptance of these would 'seriously infringe our national sovereignty'. These safeguards related to the submission of detailed accounts of operation to the IAEA and the despatch of inspectors by the Agency to collect data about fissionable materials and products.

Turkish AEC'S first report

Ankara Building of the AMF research reactor near Istanbul will be completed in the summer of this year, says the First Report on the activities of the Turkish Atomic Energy Commission. Criticality is expected in the autumn and gradually the power will be raised to 1 MW. The report also says that plans are in hand to build the AEC's nuclear centre at Sariyar, near Ankara and that an IAEA expert is advising the Commission on a long term research and training programme.

Soviet-Indonesian reactor contract

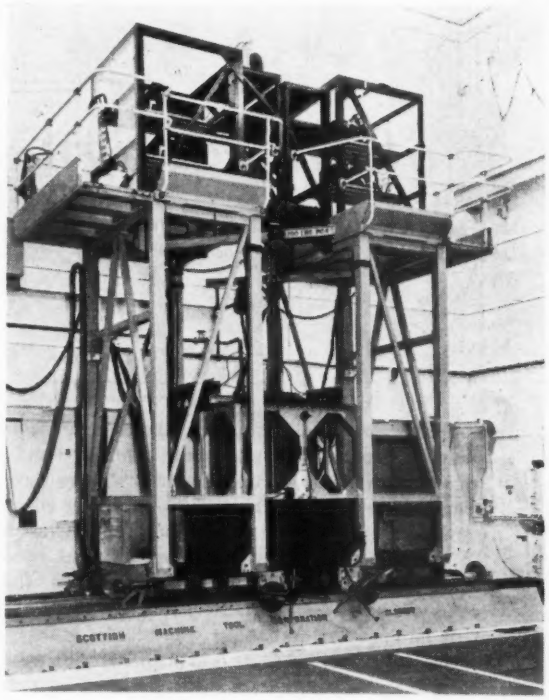
Djakarta Contracts with the Soviet Union for aid in the building of a research reactor and a critical facility were signed here recently. Under these agreements, the USSR is to send specialists to Indonesia for preparatory work involved in building the facilities and will accept Indonesians for training.

Fast Reactor Studies at Aldermaston

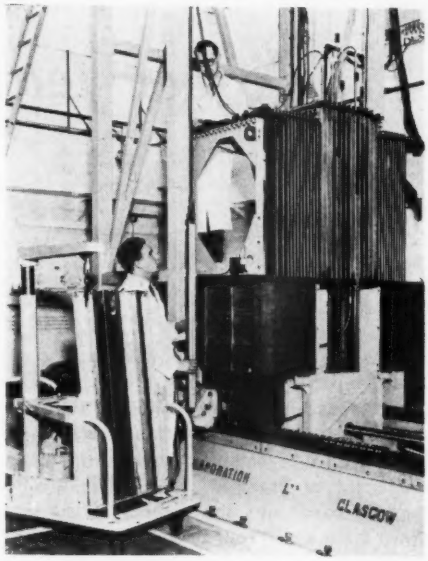
ALDERMASTON'S new low power reactor VERA, which went critical a few weeks ago, will provide experimental nuclear data associated with the fast reactor development programme. More information is required that relates to the safety of storage and processing of fissile materials.

The core of the Versatile Experimental Reactor Assembly consists of thin-walled steel fuel tubes surrounded by a natural uranium reflector—the whole forming a cylinder 4ft high × 5 ft diameter. The fuel tubes are loaded with fissile and diluent material plates 1·7 in² × $\frac{1}{8}$ in thick. By appropriate loadings, the composition and size of the reactor core may be varied to examine the nuclear characteristics of materials over a wide range of neutron energies.

Similar to other experimental facilities, for safe loading the assembly is designed to separate into two sections, the two parts being brought together slowly by remote control. Using an accelerator, neutron bursts can be generated to permit measurements of reactivity and time-dependent behaviour. During operation power will not exceed 100W, therefore no special cooling is required.

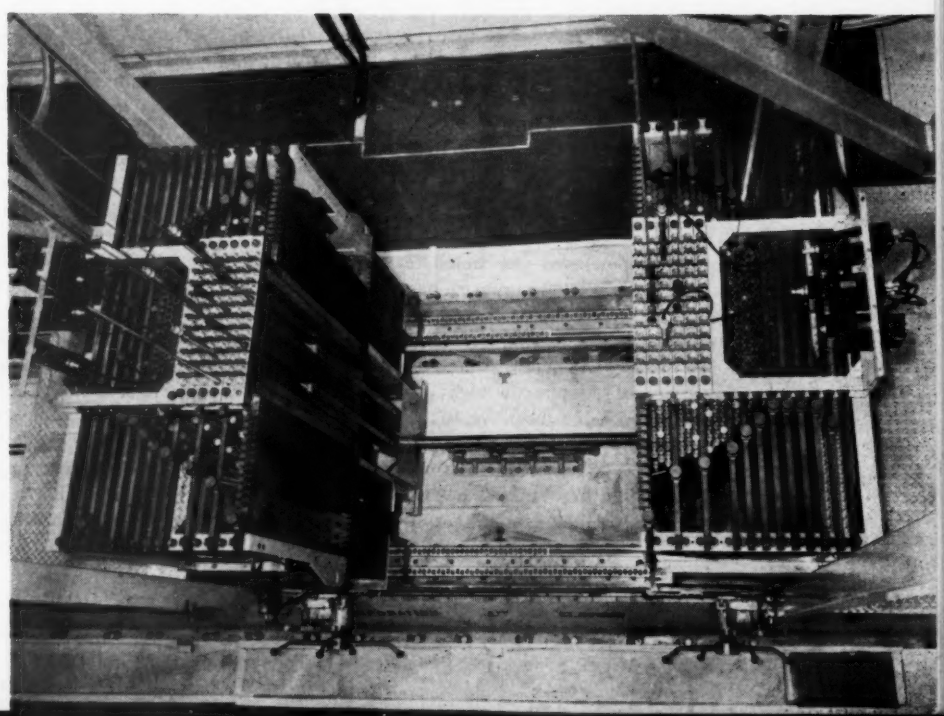


◀ Housed in a large concrete cell, the two halves of Aldermaston's new low power reactor are now together and are in the operational position



▲ Loading the fuel elements into the reactor core

Vera is shown here in the safe loading position, with the two halves separated. Looking down on the core, the thin-walled steel fuel tubes and the natural uranium reflector can be seen ▶



CONTRACTORS

SCOTTISH MACHINE TOOL CORPORATION LTD
Rails and platform

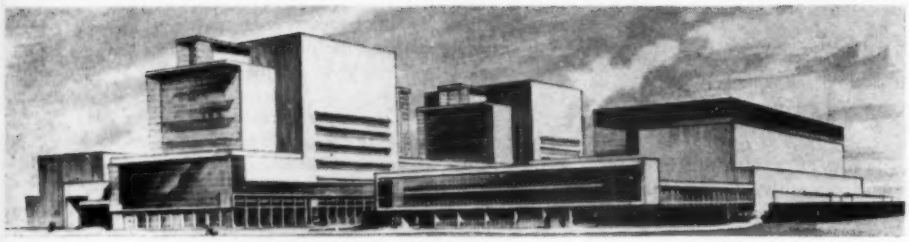
MATTHEW HALL & CO. LTD
General framework

HESTON AIRCRAFT & ASSOCIATED ENGINEERS LTD
Fuel element boxes

PALATINE TOOL & ENGINEERING CO. (SURBITON) LTD
Control drawer unit

WESTERN MANUFACTURING (READING) LTD
General engineering

W. E. CHIVERS & SONS LTD
Main building contract



The Central Electricity Generating Board issued their enquiry for Dungeness Nuclear Power Station on October 2, 1958, with an invitation to return a tender on March 14, 1960. The Nuclear Power Group obtained the contract for this 550 MW (net) station, and work began in August, 1960.

DUNGENESS NUCLEAR POWER STATION

1. Novel features of the design

by R. D. VAUGHAN, B.Mech.E., A.M.I.Mech.E.,
Chief Engineer of The Nuclear Power Group

DUNGENESS IS the first nuclear power station of the gas-cooled type to be offered at a contract price of less than £100/kW and has thereby achieved the reduction in cost to be expected from another year's technical progress. There have been no startling changes in layout, which is still reminiscent of Bradwell, Latina, Hinkley Point and Trawsfynydd, except that the number of gas circuits has come down from six to four per reactor. The gas pressure has increased to 283 lbf/in²a compared with 255 lbf/in²a on Trawsfynydd. There will also be a modest advance in the electrical output per tonne of uranium fuel.

However, the biggest departure from established practice for reactors of this type has been the adoption of a reactor gas inlet temperature of 250°C in association with a reheat steam cycle and direct steam turbine drive to the blowers. These changes have led to a thermal efficiency which is very high for a magnox reactor, without any significant increase in the operating temperatures of the uranium fuel or its canning material.

GAS PRESSURE

In the development of gas-cooled reactors, an increase in the coolant gas working pressure has always been found worthwhile, although for steel vessels it is expected that the advantages of increasing pressure will be very small above 300 lbf/in². Dungeness is no exception. In fact, with the possibility of adopting a high gas inlet temperature, there was considerable incentive to go to the highest gas pressure possible.

The pressure is determined by the maximum thickness of steel plate that can be obtained in satisfactory quality and welded on site for the reactor vessel. At Latina power station, a vessel of comparable dimensions incorporating some 4½ in plate has already been fabricated and pressure tested and material of this thickness will be used for the support course in the Dungeness vessel. The plate for the remainder of the vessel will be of 4 in general thickness. To keep the shell below the temperature at which creep would become significant, internal insulation, formed of layers of dimpled stainless steel foil, will be fitted to those parts of the vessel in contact with reactor outlet gas.

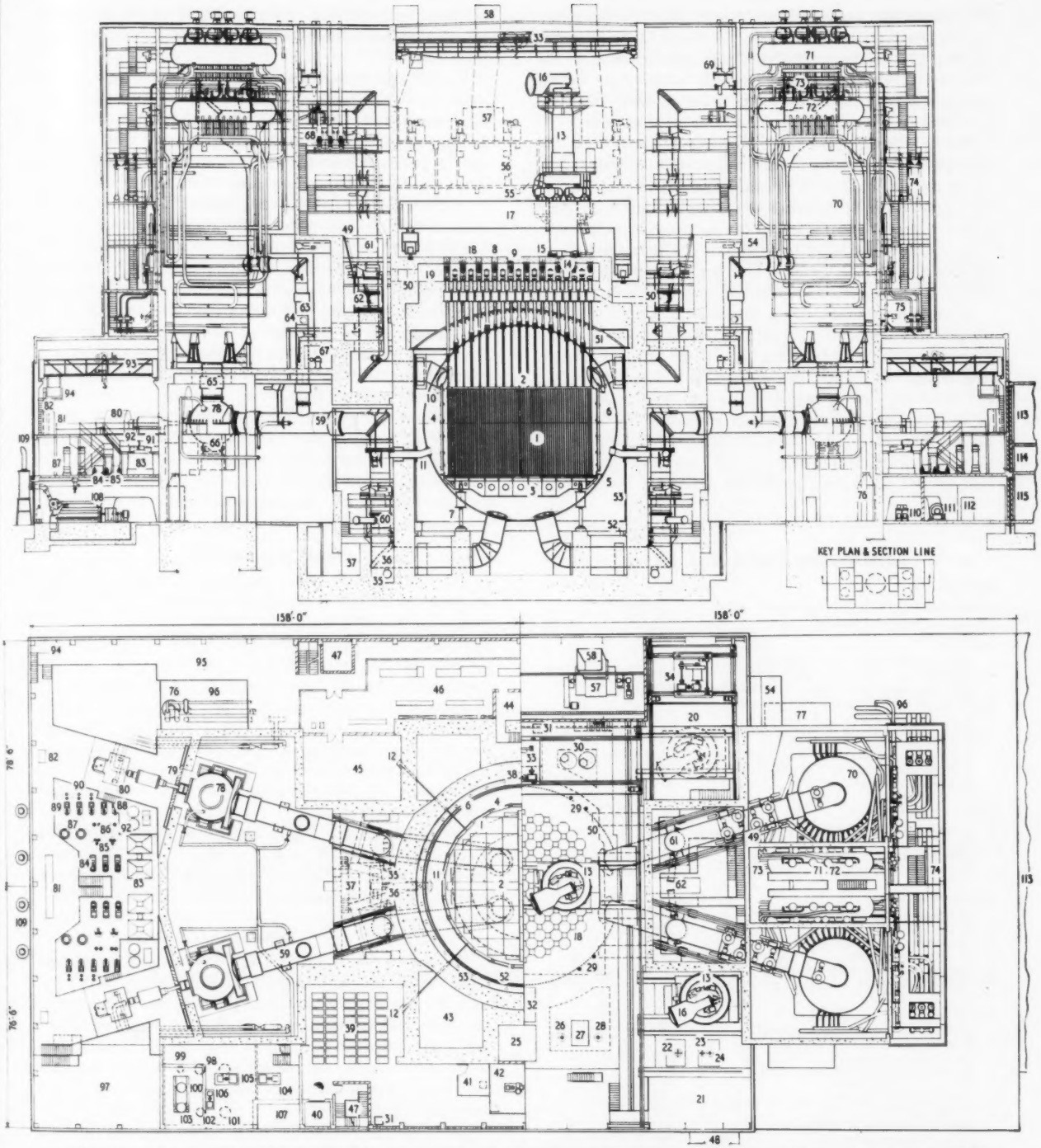
The vessel will be 62 ft 6 in diameter and with a 4 in plate thickness ; this leads to a gas working pressure of 283 lbf/in²a.

REACTOR GAS INLET TEMPERATURE

None of the earlier magnox reactors in the UK has a gas inlet temperature higher than 200°C. Designers have obviously found it economic to arrange for a fairly big temperature rise in the coolant gas and a low mass flow, in order to economize on blowing power. It should also be remarked that the early designs were all based upon dual pressure steam cycles with modest thermal efficiency, similar in essence to the Calder Hall steam cycle.

The extra gas pressure in Dungeness has made it possible to operate with a smaller gas temperature rise in the reactor without excessive blowing power and so raise the general level of gas temperatures and improve the steam cycle. The gas inlet temperature will be 250°C and the gas outlet temperature 410°C.

To take full advantage of the increase in gas temperatures and also to reduce wetness in the turbine exhausts it is worthwhile to introduce a certain amount of reheat to the cycle. This has been facilitated by the adoption of back



1 Graphite core; 2 Charge pans; 3 Diagrid; 4 Core restraining structure; 5 Gas seal; 6 Pressure vessel shell; 7 Pressure vessel supports; 8 Reactor charge standpipes; 9 Reactor control standpipes; 10 CO_2 fairings; 11 Thermocouple branches; 12 Wigner probes; 13 Charge machine; 14 Charge machine chute headbox; 15 Charge machine make-up shield; 16 Reactor television camera; 17 Charge machine gantry; 18 Operating floor slabs; 19 Pile cap; 20 Charge machine maintenance bay; 21 Charge machine fuel bays; 22 Fuel loading hole; 23 Emergency fuel unloading hole; 24 Normal fuel unloading hole; 25 Hoist well; 26 Control rod assembly maintenance hole; 27 Removable slab for absorber magazine withdrawal; 28 Absorber & charge plug assembly maintenance hole; 29 Void viewing holes; 30 Turrets, cemetery holes; 31 Ventilation duct; 32 Removable cover over storage well; 33 Charge hall crane 20 ton; 34 Charge machine maintenance bay crane 20 ton; 35 Debris removal ducts; 36 Debris removal preparation rooms; 37 Debris removal operation rooms; 38 Thermal column; 39 Fuel store; 40 Fuel lift; 41 CO_2 monitoring room (provisional); 42 Contaminated ventilation plant room; 43 Storage void; 44 Ion chamber room; 45 Thermocouple marshalling room; 46 Reactor switchgear room; 47 Lift; 48 Cooling pond transfer duct; 49 Shield cooling system air inlet; 50 Pile cap cooling air inlets; 51 Thermal dome; 52 Shield cooling air inlet ring main; 53 Shield cooling side annular duct; 54 Shield cooling fan suction ducts; 55 Shield cooling suction chamber; 56 Shield cooling fan filters; 57 Shield cooling fans; 58 Shield cooling fan exhaust stacks; 59 Reactor inlet CO_2 ducts; 60 Reactor inlet CO_2 isolating valves; 61 Reactor outlet CO_2 ducts; 62 Reactor outlet CO_2 isolating valves; 63 Bye-pass CO_2 ducts; 64 Bye-pass CO_2 isolating valves; 65 Blower inlet CO_2 ducts; 66 Blower compensating CO_2 branches; 67 CO_2 duct isolating valve remote operation rooms; 68 Reactor CO_2 relief valves & filters; 69 Boiler CO_2 relief valves & filters; 70 Boilers; 71 Boiler H.P. drums; 72 Boiler L.P. drums; 73 Steam drum rooms; 74 Boiler steam & feed piping annexe; 75 Boiler feed operating corridor; 76 Boiler blow-down tank; 77 Boiler house ventilation; 78 Blowers; 79 Blower casing shield doors; 80 Blower turbines; 81 Blower & boiler gaugeboards; 82 Blower Switchboards; 83 Blower main oil tanks; 84 Blower L.P. oil pumps; 85 Blower L.P. oil strainers; 86 Blower L.P. oil filters; 87 Blower oil coolers; 88 Blower turbine servo oil pumps; 89 Blower seal oil pumps; 90 Blower seal oil filters; 91 Blower seal oil degasifying tanks; 92 Blower seal oil pressure tanks & regulators; 93 Blower house crane 20 ton; 94 Blower house crane access platform; 95 Cable tunnel; 96 Steam & feed pipes; 97 Loading bay; 98 CO_2 bye-pass filters; 99 CO_2 drier filter; 100 CO_2 drier; 101 Main blow-down filter; 102 Auxiliary blow-down filter; 103 Overfilling vent & blow-back filters; 104 Change room; 105 Main CO_2 vacuum pumps; 106 Auxiliary CO_2 vacuum pump; 107 Loading well; 108 Essential supply diesel generators (Figs. 1 and 2); 109 Diesel generator silencers & exhausts; 110 Essential supply batteries; 111 Motor generator set; 112 Switchgear; 113 Control room; 114 Cable room; 115 Active change.

pressure turbine drives for the blowers. Steam is generated at two pressures in the boilers, but the H.P. steam passes entirely to the blower turbines and then returns to the boilers for reheating to the original temperature before joining the L.P. steam flow to the main turbines. The main machines thereby receive steam at one pressure only.

With a reheat steam cycle it is important to note that the optimum reactor gas inlet temperature is higher than for a conventional dual pressure cycle. This will explain the apparent anomaly wherein reactor designs with quite different gas inlet temperatures can still remain competitive. The optimum gas inlet temperature for Dungeness from the point of unit generation cost lies between 240°C and 250°C. The optimum for plant cost may be a little lower.

A consideration of equal importance in the selection of gas inlet temperature is the behaviour of the graphite throughout the life of the reactor. At the time the Dungeness design was undertaken the available data on graphite indicated the rate of accumulation of Wigner energy to be such that irradiation annealing would have to be carried out at least once during the working life of the reactor. To avoid the complication, and possible hazards, of this operation, it was considered preferable to design for a higher graphite temperature, which is achieved in the most straightforward manner by raising the gas inlet temperature to 250°C.

The position in regard to Wigner energy has eased somewhat and it would now be more accurate to say that a gas inlet temperature of 250°C will keep the peak rate of energy storage down to half that which would occur with a gas inlet temperature in the region of 200°C. In other words, the Dungeness core would last twice as long as another core operating at a similar neutron flux, but with cooler inlet gas, before annealing became necessary.

The growth of graphite is now just as important to the designer as energy storage and here again, high operating temperatures are desirable. With 250°C gas inlet temperature, it is calculated that the rate of growth of graphite will be reduced by a factor of 10, so that gaps between bricks can be much less than on earlier designs.

There are two further advantages of the high gas inlet temperature which are less easy to evaluate numerically. The life of the fuel elements in the bottom half of the reactor will improve owing to greater ductility of the canning material and reduced growth of the uranium. The reactor vessel will also be less susceptible to irradiation damage because of continuous annealing at the higher temperature.

DUNGENESS TECHNICAL DATA

PERFORMANCE	
Net electrical output (station)	550MW
Heat output per reactor	835MW
Efficiency	32·9%
Reactor gas bulk outlet temperature	410°C
Reactor gas inlet temperature	250°C
Nominal max can surface temperature	442°C
Nominal max uranium temperature	563°C
H.P. steam pressure at blower TSV	1410lbf/in²a
L.P. steam pressure at main TSV	392°C
L.P. steam pressure at main TSV	550lbf/in²a
L.P. steam temperature at main TSV	391°C
Feedwater temperature	180°C
FUEL	
Number of fuel channels per reactor	3876
Number of elements per channel	7
Dimensions of uranium rod	38·3 x 1·10 in dia
Total weight of uranium per reactor	300 tonne
CORE DIMENSIONS	
Diameter of active core	45ft 4½in
Height of active core	24ft 4½in
Diameter of reflector	50ft
Height over reflectors	28ft
Lattice (square pitch)	7·75in
Channel diameter	3·875in
GAS CIRCUIT	
Mean diameter of reactor vessel	62ft 6in
Reactor vessel general thickness	4in
Gas working pressure	283lbf/in²a
Number of gas circuits per reactor	4
Diameter of gas ducts	6ft 6in
Power input per blower	7MW
Overall height of boilers	75ft
Internal diameter of boilers	23ft 6in
Shell thickness (graded)	3⅛in to 2⅛in
TURBO-ALTERNATORS	
Number of main turbo-alternators	4
Continuous maximum rating/set	142·5MW
Speed	1500 rev/min
Generator voltage	13·8kV
Vacuum	28·9 inHg
Exhaust wetness	14·3%
Total circulating water quantity	353,000 gal/min
LAYOUT	
Distance between reactor building centres	426ft
Length of reactor building	316ft
Length of turbine house, only	385ft

REACTOR LAYOUT

The extra gas pressure has made it possible to effect an economy in layout of the reactor unit by reducing the number of gas circuits to 4 per reactor. In the arrangement drawings of the reactor unit (Figs. 1 and 2) it will be seen that the reactor inlet ducts now go very easily into the vessel below the core support grid. It has not been possible to bring the inlet forgings on adjacent circuits any closer together and this means that the bottom gas ducts are not co-planar. However, the portions of each duct carrying the expansion bellows are themselves in one plane and the amount of torsion sustained by the bellows hinges will be extremely small.

The arrangement of gas circuits in pairs leads to a symmetrical layout of each individual blower house and the overall span of the reactor building will be no greater than it was for Bradwell.

BOILERS

The boilers for Dungeness will have natural circulation on the steam side instead of assisted circulation which has been the rule so far. Natural circulation has been adopted for reasons of economy and reliability in operation. From the safety point of view, it is re-assuring to regard the boilers as a reliable sink which will remove heat from the gas circuit independently of circulating pumps or their electrical supply.

For a natural circulation boiler, it is necessary to raise the steam drums as high as possible and the drums and valves for each pair of boilers have been grouped together in a shielded room high up in the boiler house. In addition, of course, to the normal economizing, evaporating and superheating tube banks, there will be some reheat banks to handle steam returning from the blower turbines. These items are described in more detail elsewhere.

The boiler vessels themselves will be very large, the diameter of the shells being 23 ft 6 in and the height 75 ft; because of this, certain departures in design have been

necessary. The shell thickness varies from $3\frac{7}{8}$ in at the top to $2\frac{1}{8}$ in at the bottom thereby taking advantage of the drop in gas temperature down the boiler and reducing the shell weight. Because of the large diameter and the high temperature of the gas leaving the boilers, there is quite a serious expansion problem with the boiler supports. Rocker supports will therefore be adopted in place of the skirt which has been used on earlier designs.

REACTOR CORE AND FUEL ELEMENT

The overall dimensions of the reactor core do not reveal any startling departures from current practice. Both the lattice pitch of $7\frac{1}{4}$ in and the fuel channel diameter of $3\frac{7}{8}$ in bid fair to become British standard core dimensions for reactors of this type. The utilization of the vessel volume is marginally higher than was achieved on Trawsfynydd.

The engineering design of the core, as described elsewhere, will be similar to the design adopted for Latina. In this design, a square lattice of fuel channels is made up with alternate octagonal and square bricks keyed to each other in such a way that the overall core dimensions will be independent of foreseeable changes in the dimensions of the graphite bricks themselves. The design will also ensure that the straightness of fuel channels is independent of dimensional changes due to graphite growth or temperature.

The fuel element for Dungeness will be similar in many respects to the fuel elements for Bradwell, Latina and Hinkley Point. It is not possible to justify on economic grounds any departure from the solid rod design while the available gas pressures and secondary heat transfer surfaces set a limit to the channel heat rating. A uranium bar of 1·1 in diameter has been chosen. Smaller diameter bars were considered in order to reduce the tonnage of fuel in the reactor, but it was found that an increase in the price per tonne of fuel outweighed any saving on total weight, particularly in the calculation of unit generation cost.

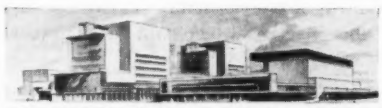
The adoption of a thermodynamic cycle of high efficiency has led to a modest fuel heat rating so that the can surface temperature will be higher than on other contemporary designs. However, both the maximum can surface temperature and the maximum centre uranium temperature now lie very close to the limiting values permissible for magnox and uranium, namely, 480°C and 615°C. It follows that the fuel is being used to its best advantage.

BURST CARTRIDGE DETECTION

On only one other feature has there been any major advance in design philosophy and this is on the equipment for detecting burst cartridges.

The system will be comparable in its broadest aspects to that already in use on Bradwell. A selector valve at the reactor itself will select the gas from 32 channels before it passes through a single pipe across the pile cap to the precipitator room. Whereas on Bradwell, the selector valve was located beside the control rod head and outside the reactor vessel itself, the Dungeness selector valve will be located within the standpipe, saving upwards of 300 ft of stainless steel tubing per standpipe. It will also be possible to change the selector valve with the reactor on load in a time of 20 minutes.

The system will provide for a two speed scan to detect the two basically different types of can failure anticipated. Firstly, there may be failures due to manufacturing faults which will be rapid but will give strong signals. These will call for a fast scan of relatively low sensitivity. Secondly, there may be slow developing faults due to cavitation or some other metallurgical feature of the can material. These faults will be better detected by a slow speed scan of high sensitivity. The way in which the two scans can be superimposed is described elsewhere.



DUNGENESS NUCLEAR POWER STATION

The design ensures that dimensional changes will not affect the straightness of the fuel channels

2. *Development of the graphite core*

by S. B. D. FLETCHER, B.Sc., A.M.I.Mech.E., A.M.I.E.E.,
Electrical Department, The Nuclear Power Group

SINCE THE DESIGN of the first round CEGB stations, there has been an improvement in the understanding of the problems associated with graphite. So much so, that it has become an obvious advantage to design a core that does not depend, mechanically, upon the properties of this irrational material.

The early cores were evolved largely on an expectancy that graphite growth would dominate. They used a brick and tile construction, the whole being held as a tight pile by pre-tensioned compensated restraint bands. If, as is now known, graphite can shrink after irradiation, this principle has drawbacks. Palliatives, such as the introduction of zirconium spacer pins are successful, but being nuclear parasites, are undesirable.

KEY SYSTEM

At the time when the cores of the first stations were modified to cater for shrinkage, many ideas were tried out. These included the building of a model using a 10 × 10 matrix of full-size reactor tiles, using axial keys on the outside faces of the tiles. It was foreseen that these keys would run the full length of the core bricks, and, since these are square, there would be four keys per brick forming a system

on two axes. The model showed this system to be unstable, and eventually, the pin system was used.

It was appreciated that the key system was very similar to those being used by the French and others, and we were assured that these systems were stable. However, the French design used hexagon bricks and thus a triangular lattice, and we did not wish to depart from a square lattice core.

At the same time it was realized that the pinned core would be unsuitable for a station in an earthquake zone. Such a reactor was being built at Latina. In the search for a solution that gave the stability of the hexagon brick core, but retained a square lattice, attention was drawn to a very old idea, abandoned for Calder. This coupled axial keys on the square faces with cruciform keys at the corners. Each brick would thus have eight keyways cut in it; on each of the faces would be a long rectangular key, and at each corner, one arm of a cruciform key.

Cruciform key

A cruciform key is fragile and expensive. Investigations were made to find a method of strengthening this feature, and it was found that stability could be obtained with the use of a single key, joining two diagonally adjacent bricks. Thus, every other brick would be constrained by both the square and the diagonal key patterns. The remaining intermediate bricks would be enclosed in a square pattern, within the major one. Many tests have shown this system to be stable. It was logical to enlarge the bricks containing the diagonal keys, to provide more strength, and they became octagonal in shape. This last step gave in principle the octagon and square pattern core. It was appreciated, and proved that provided the perimeter of the core could be held stable, and the key axes tied into it, then the columns of the core would be stable even with large gaps between them. It was also found that provided the keys overlapped the brick end junctions, then column alignment could be achieved without recourse to end features such as face keys. In the absence of tiles, it is possible to provide a short spigot from one brick into the next, not with a view to aiding alignment but to reducing brick-end gas leakage.

GAS PRESSURE EFFECTS

Concurrently with these tests, an analysis was made of the effect on the core of a rapid decrease in gas pressure. Under these conditions, gas trapped in the gaps between the bricks can exert a bursting force on the core and on the restraint members. A rigorous dynamic solution of the problem was evolved, and this showed that if the core were held closed at the reflector (sides, top and bottom) bursting pressures of the order of 30–40 lbf/in^2 would occur in the Dungeness core. This was quite unacceptable, for it would have meant the permanent installation of an enormous supporting structure to protect against a highly improbable fault.

Two alternatives were immediately obvious, the first being to vent the core interstitial spaces in some artificial way, and the other to arrange for a definite opening up of the core at the top.

The former is not technically attractive. The latter requires the periphery of the core to expand thermally at a greater rate than graphite, which with the octagon/square pattern core, is the natural result of a steel ring periphery. The core is surrounded by a steel cage without compensation or pre-tension. Simple restraint beams are tied into the outer bricks at each layer and connected to the cage by articulated jacking screws, to permit adjustment on erection. The expansion of the cage, acting through the jacking screws and restraint beams, controls the expansion of the core.

Tests carried out to prove the maintenance of the lattice included one to illustrate the movement of the bricks when subjected to unbalanced (sideways) gas forces. This state of affairs occurs in the outer regions of the core. In estimating the likely gas pressure load on a brick, it was found that this would be at most of the same order as the brick's own weight. A section of core was therefore erected on its side, supported at the top by mandrels mounted on ball bearings and running on rails, and at the bottom by a beam with ball bearings between it and the lower bricks. A few of the outside keys at the sides of the model were also extended, and fitted with bearings running on angled tracks. These were installed to minimize boundary effects at the unsupported sides of the model. By lifting and lowering the bottom support beam the core could be seen to close and open as it would in the reactor. It was possible from this test to get an idea of the forces required to close the core.

The same model was useful in studying the effects of key removal, a condition which might occur accidentally (breakage) or deliberately (due to the presence of an interstitial channel). Stability rules for the positioning of these latter channels were easily established.

CORE RESTRAINTS

Reverting to core restraint, it is obvious that unless the bricks are of such a size that they abut, the lattice at any level will be dictated by the setting of the support beams from the cage. Thus at the time of installation it is possible to arrange the lattice at successive levels so that the outer channels are tilted (either inwards or outwards) in any predetermined way. Since the thermal expansion is dictated by the steel cage and is thus reasonably predictable, it is possible to preset the channels when cold to achieve an optimum alignment when hot.

With the top of the core expanding as steel, a secondary but useful advantage is obtained. Hitherto, the alignment of pressure vessel penetrations has been a matter of compromise, as differential movements exist between the nozzles and core. The present design does much to reduce these movements and to ease the problem of chute or standpipe assembly entry.

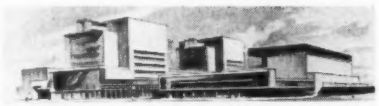
It was a further logical step to remove ball races from the bottom of the core, and mount the graphite and support strut lantern straight on the support plates. Sealing is necessary between the plates, and their supports on the diagrid must permit differential expansion between plates and grid to occur without cumulative displacement of the plates, or damage to peripheral brackets. These, however, are not new problems, nor are they specific to this type of core. It is important that the relative centres of channels from plate to plate should be maintained, and this is achieved by a system of keying between diagrid and plates which permits wide temperature differentials.

Channel sleeving is not necessary in the case of the Dungeness core, as the inlet temperature is 250°C, and

accumulation of stored energy in the graphite remains low throughout the operational life of the reactor. Even on pessimistic data, irradiation growth will be small.

From the experience gained in assembling various models using full size bricks, it apears that the seeming complication of keys is well offset by the absence of tiles. Erection is expected to be more straightforward than with former types of core. Equally, the absence of pre-tensioned restraint bands removes time-consuming and troublesome erection operations.

It is felt that the core is efficient and simple, achieving a marked freedom from the changes in graphite data that have bedevilled earlier stations. It is significant that with the exception of restraint cage stiffness, the same design is used for two stations, Latina (which includes a seismic load component) and Dungeness.



DUNGENESS NUCLEAR POWER STATION

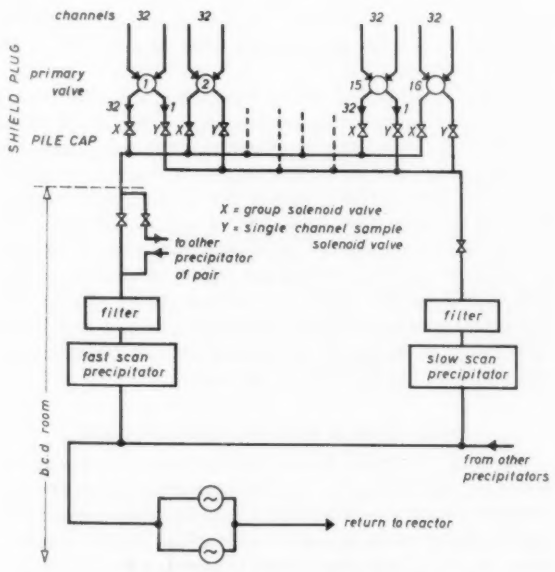
All channels can be examined by the high-speed scanning system roughly once every six minutes

3. The burst cartridge detection system

by J. O. JOSS, B.Sc., A.M.I.E.E.,
Electrical Department, The Nuclear Power Group

THE BURST CARTRIDGE DETECTION system has been evolved as the result of a study of the characteristics of bursts experienced at Calder Hall. Such a study shows that the signals obtained on the b.c.d. gear can be generally classified into one of two categories. Firstly, there are those bursts which occur suddenly, grow extremely rapidly and which may require emergency action to minimize spread of contamination within the coolant circuits. The second category includes channels from which a very slowly increasing signal is obtained, taking many days or even weeks to reach a level which requires their removal from the reactor. It was also suspected that some of the latter category might be incipient fast failures, so that an early warning of their existence would be valuable.

To meet the above requirements the dual system shown in Fig. 1 has been developed, so that groups of channels are scanned at high speed, while single fuel channels are scanned independently with a relatively long overall scanning time.



Channel monitoring system (Fig. 1)

The high speed scanning system has a relatively low sensitivity, but has the fast scanning cycle time of about 6 min. The slow speed system sensitivity is the maximum practically achievable using a feasible gas sample flow, and the system overall cycle time is approximately 3½ h. Each reactor is monitored by 16 wire precipitators, 8 allocated to each of the scanning systems, together with a duct precipitator and spare units.

PIPEWORK AND SELECTOR VALVES

The sampling pipes draw gas from the channel entry sleeve in the chargepans on top of the core structure. The pipes from 32 fuel channel exits are grouped into a boss, there being one of these surrounding each control rod channel. From each boss to the bottom of the standpipe above there extends a tube bundle, which is withdrawable from the reactor in the shut-down condition.

The control standpipe biological shield plug incorporates at its lower end 32 pipes which mate with those of the tube bundle, and lead the gas samples to the b.c.d. selector valve, situated in the shield plug. This valve permits either a group sample from all 32 inlets to be drawn off into a group outlet port, and/or a single channel sample from any one channel through a separate outlet port. The valve is of the rotary type. It is replaced by means of the charge machine, this operation being carried out on load.

Placing the valve so close to the point of sampling means that the ' dead time ' in the cycle, when stagnant gas is being passed through the pipework and precipitators, is reduced to the minimum, while retaining adequate shielding of the valve itself.

From the valve, the two outlet pipes pass out of the standpipe above the pile cap level. A group of solenoid valves is mounted close to each standpipe, and connected to it by flexible pipework.

These valves control the outlets to fast scan, slow scan and burst monitoring pipework.

FAST SCAN SYSTEM

Sixteen groups of samples are handled by each fast scan precipitator. The precipitators are paired, and a system of solenoid valves and cross-over pipework permits the samples to be passed to either precipitator of the pair. Normally, each samples its own 16 samples in rotation, but facilities are included whereby the precipitators can operate on a 'home' and 'away' sequence; the alternate scan change-over in this case is automatically controlled by the main sequence controller. Ratemeter outputs are switched in synchronism, so that the count signal from every sample ultimately appears at the same display unit.

Since the data points are few in number, a simplified, legible, visual display system has been devised. The display for each precipitator consists of a 10 in recorder, handling the ratemeter output for 4×4 group samples. Alarm levels are set individually for each group.

SLOW SCAN SYSTEM

Each slow scan precipitator samples in succession the channels associated with 16 selector valves. These valves are indexed in turn by signals from the master controller. Since in this case the gas sample flow is comparatively small, precipitator wire snatch time has been optimized to minimize 'smear' between successive samples.

Since the quantity of discrete data is large in the case of this system, consideration was given to the utilization of a computer for handling the outputs. By this means all redundant data would be filtered out, and apart from a routine log printed once per day or week, only significant outputs reach the printer.

It was felt however, that elaboration in the case of this essentially early warning system was not warranted. Instead the simple teleprinter scheme shown in Fig. 2 was incorporated into the design, continously operating using 'fan fold' log sheets. All data is printed out, significant readings being colour coded, and after an appropriate storage period, the major part of the record sheets will be scrapped. The system also incorporates a tape puncher, by means of which the channel activity levels and sample indentification code numbers can be recorded in code form on paper tape. The data over a period for one channel can then be read off and printed by a tape reader.

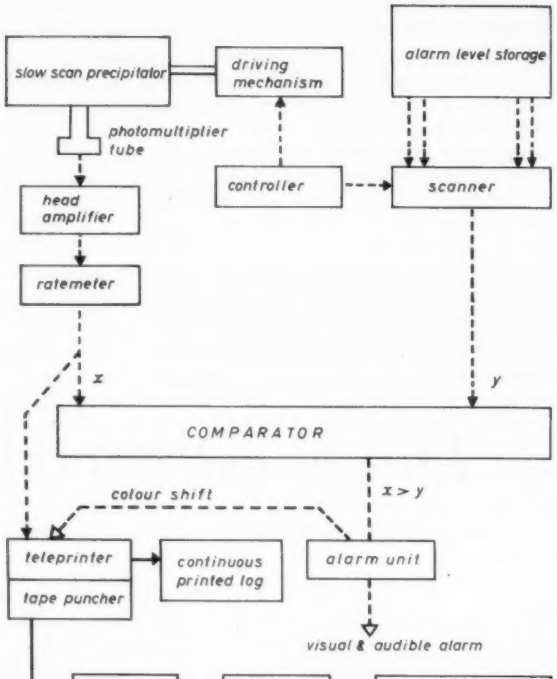
Slow scan alarm levels are set for each individual channel by means of a peg-board system, mounted alongside the relevant precipitator.

HIGH COUNT FACILITIES

Two spare precipitators are provided which may be substituted for a faulty slow-scan unit, used to locate or continuously monitor a suspect channel, or to monitor a channel being refuelled.

Selection of these precipitators for high count service is carried out completely from the main Station Control Room. From the control point a search procedure can be initiated, involving the scanning of the channel controlled by a single rotary selector valve, to determine which one of a group is emitting the fission product signal. If the suspect channel is already known, or after it is identified by the search scan, the spare precipitator continuously monitors this channel.

As a measure of flexibility, pre-selection means enable several channels to be scanned in succession by the spare precipitator. The time between successive readings on any



Slow scan data handling (Fig. 2)

one channel increases proportionately to the number of channels being monitored. For this reason, six channels may be considered the limit on one precipitator for quasi-continuous monitoring, the repetition time under these conditions being just under three minutes.

DUCT MONITORING SYSTEM

Despite the high speed of the fast scan system, it has been deemed desirable to include a duct monitoring precipitator. This will draw a common sample from all four inlet or all four outlet ducts.

Normal practice with the fast scan system would be to wait for a second confirmatory reading after a high count alarm is given, and depending on the rate of rise to locate the channel, shut-down, or trip the reactor. A single reading must always be dubious as a reason for an emergency reactor shut-down, since the possibility of detector failure must always exist. However an extremely rapid rise of activity, of the order of 10% per minute would be good cause for just such a measure, and such a fault should give a confirmatory signal quickly from the duct precipitator, which will have a repetitive cycle of the order of 30 s. The sensitivity of this system is, of course, relatively poor.

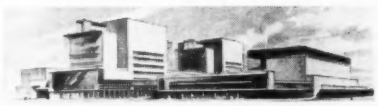
SHUT-DOWN MONITORING SYSTEM

Within a very short time of a shut-down the short-lived fission products disappear, and the wire precipitators become useless for burst fuel element detection. However the uranium rod of a faulty can is exposed to the coolant, and the powdery oxide resulting from this contact is gamma-active if the fuel element has been irradiated for some time. The wire precipi-

tators are preceded by high efficiency filters, and in these are mounted scintillation crystals and photomultiplier tubes. The outputs after amplification are displayed on recorders in the b.c.d. room.

GAS-RETURN COMPRESSORS

The differential pressure necessary for circulation of the gas samples from channel or duct, through the pipework, filters, precipitators and back to the reactor is provided by a pair of centrifugal compressors. These are of the gas-bearing type, driven by 2 pole, 200 cycles/s motors, each provided with its own frequency changer. Normally one compressor only is running, but the second starts automatically in the event of failure of the running one.



DUNGENESS NUCLEAR POWER STATION

Back-pressure turbine drive has been used for the first time in the UK

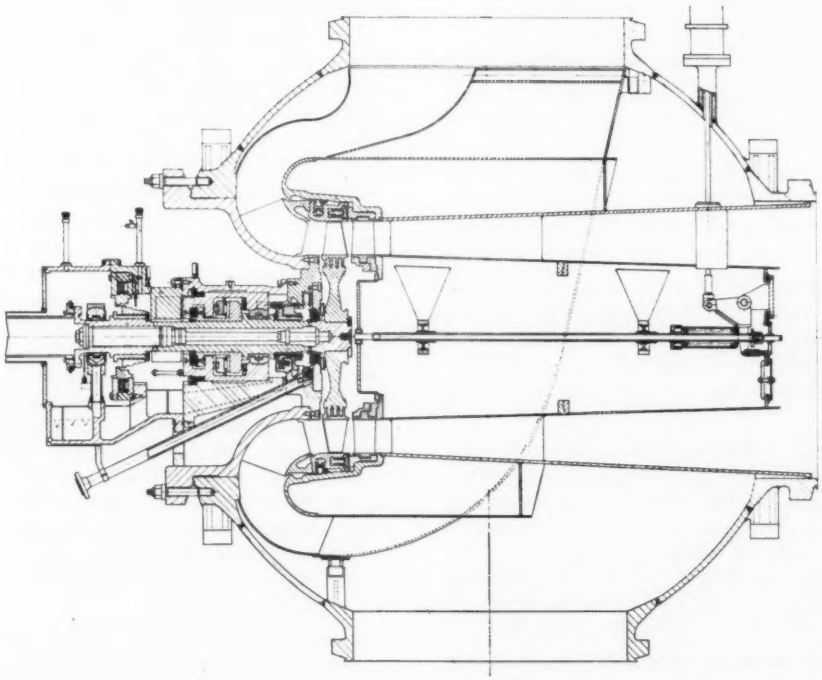
4. Gas blowers and drives

by J. ARMOR, B.Sc.,
Mechanical Department, The Nuclear Power Group

CARBON DIOXIDE coolant circulation through the reactor is effected by four axial flow blowers operating in parallel at identical speeds. A sectional assembly of one of these machines is shown in Fig. 1. The blowers are of single stage design with an overhung impeller contained in a spherical pressure casing and having predicted characteristics as shown in Fig. 2. The power input at the blower coupling at normal speed and duty is nearly 9000 hp for an overall isentropic efficiency of 82%.

The blower casing is positioned directly underneath the boiler and the gas has, therefore, to be turned through 180°C inside the casing in order to maintain the preferred duct arrangement. To reduce flow pressure losses through the casing while also giving an attractive mechanical design, a spherical outer shell with suitable internal fairings is used. To improve the velocity profile to the rotor blading, a boundary layer control slot in the inner nose of the internal casing feeds air to the annulus just before the rotor blading.

The running seal, mounted on the blower shaft between the impeller and the first bearing, is of the oil-fed face type. The seal is maintained by oil supplied at a pressure of

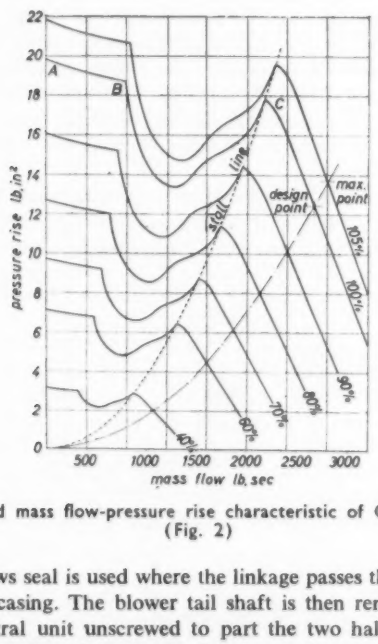


Cross-section through a blower (Fig. 1)

15 lbf/in² above the gas pressure, the oil leakage into the gas side of the seal being passed into a pressure drain tank. A white metal face bears on a collar on the shaft and is held so that it can adjust itself to any angle the shaft may take. It is also capable of limited movement in an axial direction to accommodate shaft expansion and the movement of the shaft necessary to engage the stationary seal.

INSPECTION

The stationary seal is provided to allow inspection of the running seal without reducing the gas pressure in the circuit. It consists of two metal plates which touch at the rims, one plate being mounted on the impeller and the other on the blower casing. To engage the stationary seal, the cylindrical housing containing the thrust bearing is forced axially towards the driving end of the machine by means of hydraulic pistons, causing a flange on the impeller to enter a matching spigot recess on the blower casing and bringing the stationary seal into operation. To dismantle the rotating parts, the stationary seal is engaged and held in position by a hand jacking device consisting of a mechanical linkage, screw operated from outside the casing, pushing a rod onto the rotor by means of a crank.



Estimated mass flow-pressure rise characteristic of CO_2 blower (Fig. 2)

A bellows seal is used where the linkage passes through the blower casing. The blower tail shaft is then removed and the central unit unscrewed to part the two halves of the Hirth coupling. Finally, the bearing and seal assembly is removed, leaving the rotor and its stub shaft locating on the stationary seal.

Reverse running of a blower, which could occur if its driving turbine failed, is prevented by a clutch which is automatically engaged, locking the rotor to the casing and preventing it from rotating backwards under a reverse torque. The blower shaft is helically splined to carry the anti-reverse synchro self-shifting clutch, the internally toothed ring of which is bolted to the bearing casing. A friction clutch is embodied to reduce the shock load.

The lubricating oil system is common for the back pressure turbine, pony motor and blower. Oil is also drawn from the main oil tank by the servo oil pumps to provide control oil for the turbine, and by the seal oil pumps supplying oil for the blower running seal. A pressure regulator, ensuring correct seal oil/gas differential pressure, is arranged on top of each of the two pressure drain tanks, which receive oil draining from the gas side of the blower seal. Cooling water for the oil coolers and other auxiliary equipment in the blower house is supplied from a closed circuit cooling water system containing townswater treated with anti-corrosion inhibitors from permanent dosing equipment.

Each blower is provided with a direct-coupled pony motor mounted between turbine and blower on a base which is common to the turbine inboard pedestal. The motor is a 3·3 kV, 3 phase, 50 cycle, 2 speed machine capable of driving the unit at 22% speed with full gas pressure in the reactor or 43% speed with atmospheric pressure in the reactor. In an emergency, the supply to the pony motor is switched on automatically at the lower synchronous speed, and in the event of loss of gas pressure in the circuit, the speed is raised to the higher pony motor speed. In view of the wide speed range over which the pony motor has to operate, it is provided with two separately driven 100% capacity cooling fans.

DRIVING TURBINE

The driving turbine is a back pressure machine of the multi-stage impulse type having 13 stages with a single row of rotating blades in each stage. It is designed to give the maximum availability, the necessary auxiliaries being few in number and consisting of simple standard units. The maximum continuous rating of the turbine is at 105% of normal operating speed and its normal rating (at 100% speed) corresponds to the design output of the reactor. The maximum rating is achieved by operating the turbine at increased steam pressure or with reduced back pressure.

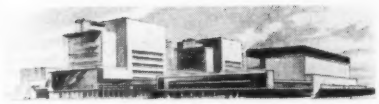
The turbine cylinder is divided along the horizontal plane only and the steam chest containing the control valves is cast integral with the top half casing, eliminating a joint between the two. The shaft and wheels of the rotor are machined from a solid forging and are homogeneous throughout. The rotor is designed to have a critical speed well above the maximum operating speed to ensure that there is vibration free running over the complete speed range.

The machines are started on the pony motors and accelerated to 470 rev/min using the low speed winding. Control of the gas flow is then effected by varying the speed of the turbines by means of a common electrical speed reference setting. When operating on manual control, this setting is supplied to the governor speeder motor, but during auto control operation, the signal from the auto control acts directly on the pilot oil system.

The speeds of the turbines can be trimmed by up to ± 5% by a differential selsyn transmitter and receiver system designed to give identical speeds over the full operating speed range. Any turbine can be selected as the master turbine by suitable switchgear in the trim circuit.

Acknowledgment

The author would like to thank Mr T. E. Adams, B.Sc.(Eng.), Manager, Compressor Engineering Department, Heavy Plant Division, AEI Ltd., Rugby, who is responsible for the design of the blowers, for his co-operation in the preparation of this article.



DUNGENESS NUCLEAR POWER STATION

Problems associated with the high inlet gas temperature have been overcome

5. *The steam cycle*

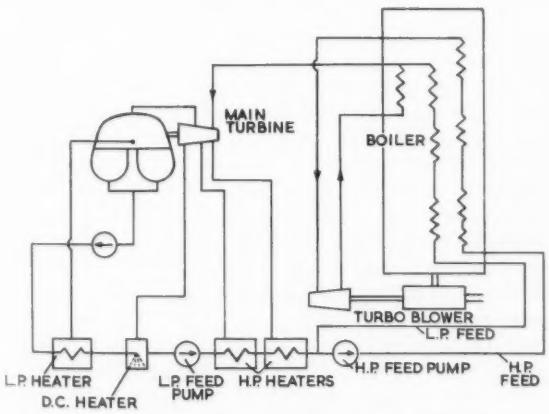
by N. BREARLEY, A.M.I.E.E.,
Mechanical Department, The Nuclear Power Group

THE DUNGENESS STEAM CYCLE has incorporated several novel features compared with its predecessors. These are the use of back pressure blower turbine drives, reheat and single pressure main turbines. These incorporations have been introduced mainly because of the uprating of the reactor gas outlet temperature and increase of the reactor gas inlet temperature to reduce the problem of stored energy in the core.

Reference to Fig. 1 shows that the cycle is basically of the dual pressure type in which steam is raised in the boiler at two pressures with a ratio of H.P. to L.P. steam 1.5:1. The high pressure steam is superheated in the boilers and is passed to the blower turbines at TSV conditions of 1410 lbf/in²a and 392°C. Each blower turbine consumes 400,000 lb/h of steam when operating at the station full load output and exhausts at 615 lbf/in²a and 284°C.

The steam is then transmitted back to the boilers and is reheated in a separate reheater bank and mixed with the L.P. steam raised in the boiler at identical conditions of 590 lbf/in²a and 393°C. All this steam is passed to the main turbines at TSV conditions of 550 lbf/in²a and 391°C. Each main turbine is designed at full load output to consume 1,348,900 lb/h of steam at a vacuum of 28.9 inHg In the four stages of feed heating, the feed temperature is raised to 180°C and splits into the appropriate H.P. and L.P. feed pressures after passing through L.P. and H.P. stages of boiler feed pumps and then to the boilers.

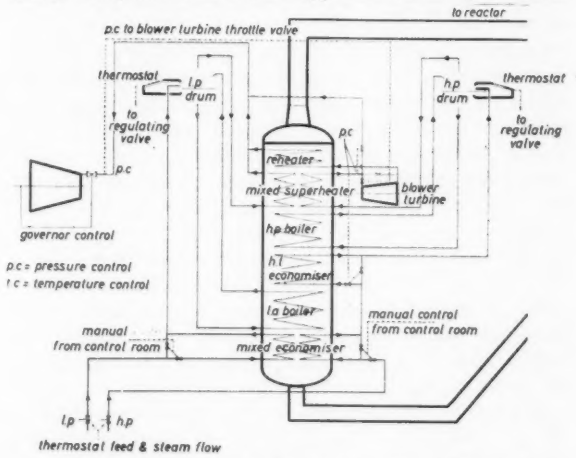
With this cycle operating with a reactor power of 835 MW and reactor gas inlet and outlet temperatures of 250°C and 410°C respectively, a net station output of 550 MW is achieved, giving a net station efficiency of 32.9%.



Diagrammatic arrangement of steam cycle (Fig. 1)

STEAM CYCLE DEVELOPMENT

For Dungeness, the problem of stored energy in the core due to operating at low reactor inlet temperatures hitherto adopted was given full consideration. The problems associated with the Calder Hall type of steam cycle when



Schematic diagram of the control system (Fig. 2)

operating at the higher reactor gas inlet temperature of 250°C were considerable. The most important of these problems was the effect on exhaust wetness of the main turbines produced by high steam pressures which resulted from increasing the reactor inlet temperature to 250°C. The final exhaust wetness would have been of the order of 19%. A further adverse effect was the resulting high blower power produced by the increased mass flow through the core associated with the reduced temperature rise across the core. The latter had the further adverse effect of reducing cycle efficiency and increasing capital and generation cost.

Clearly changes to the basic conception of the steam cycle had to be introduced to eliminate the effect of these problems and produce an optimum design consistent with a reactor inlet temperature of 250°C. Several revised cycles were considered with and without the use of reheat incorporating blowers driven from individual condensing machines and also back pressure turbines. Improvements were also made to the cycle efficiency by increased heat transfer performance of the fuel elements giving a higher outlet reactor gas temperature. The problem of high blower power was partially offset by a further increase in gas operating pressure made possible by an increase in thickness of the pressure vessel shell and redesign of the top dome of the vessel.

It was decided that the best method to incorporate reheat was to adopt back pressure blower turbines operating on all the H.P. steam generated in the boilers. All the exhaust steam would then be taken back to the boilers, reheated and mixed with the L.P. steam generated in the boilers. By this method, the problems of the high exhaust wetness and the low cycle efficiency were solved and it also gave rise to single pressure main turbines. The introduction of back pressure blower turbines and single pressure main turbines in addition to improved cycle efficiency gave marked reduction in capital and generation cost and also produced a design with an optimum inlet temperature of 250°C.

CONTROL SYSTEM

The control system (Fig. 2) has been designed to meet any load changes demanded by the grid either (*a*) automatically by grid frequency variation or (*b*) manual operation of the turbine speeder gear from the central control room.

The system has also been designed either for manual operation of both halves of the station or automatic control of one half of the station with manual operation of the other half. On automatic control, load changes are made as mentioned previously by operation of the turbine governor valves via the speeder gear which immediately reflect in a reduction or increase of L.P. steam pressure from the boilers. An increase in demanded output will cause a reduction of the L.P. steam pressure from the boilers. A steam pressure signal tapped from the L.P. steam main is transmitted via the automatic control system to the blower turbine stop valve which opens the blower turbine stop valve and allows more steam to pass into the turbine, resulting in increased blower speed and hence mass flow. The increased reactor mass flow reduces gas temperatures within the reactor, causing an increase in reactivity due to the effect of negative temperature coefficient. The power then tends to increase, restoring the reactor temperatures. At the same time, a tapping from the reactor gas outlet temperature is transmitted to the control rods which start to withdraw from the core to increase still further the reactivity and hence reactor power until the increased power demand from the turbines is met. At final steady state condition at the new power level, the L.P. pressure in the steam mains is restored to its original value.

The drop in demanded output is made by the reverse operation as described previously. On manual operation, demanded power changes are controlled in a similar manner from the main control room by operation of main turbine stop valves, blower turbine governor valves, and economizer by-passes.

Because the blower power speed characteristic of the blowers obeys approximately a cube law, at part load operation the steam demand of the blower turbines reduces at a greater rate than the H.P. steam produced by the boilers. Therefore, to prevent excess steam from blowing off through the safety valves of the boilers, two separate by-pass systems are fitted to maintain the steam pressure constant upstream of the blower turbine stop valves.

The most important of the two systems is the by-pass across each boiler H.P.H.T. economizer bank incorporating a throttle valve controlled from the blower turbines TSV upstream steam pressure. This by-pass will normally be used and will have the effect of reducing the evaporating surface and hence H.P. steam produced.

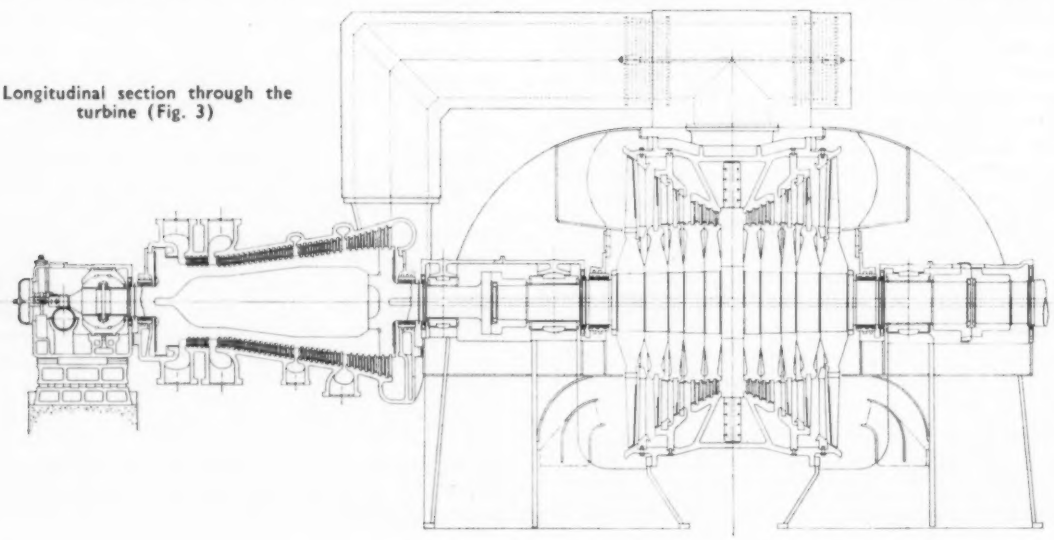
The second system is arranged to divert steam from the blower turbine stop valves and boiler reheaters by a by-pass incorporating a pressure-controlled throttle valve which reduces the steam pressure to that of the L.P. steam produced in the boilers into which it exhausts at the L.P. superheater outlet. This by-pass is also used when starting up the reactor and boilers from a cold start.

The start-up procedure is to run with the pony motors driving the blowers at 20% speed while the reactor is brought on load. At a reactor load of approximately 8%, low quality steam is produced from the H.P. boilers which is passed direct to the L.P. steam mains by-pass and then to the dump condensers which are situated in the main turbine hall. By this means, the boilers are brought up to full operating conditions simultaneously with the reactor while the blowers continuously operate at 20% speed. At a reactor power output of 20%, the turbines take over from the pony motors at full operating steam conditions.

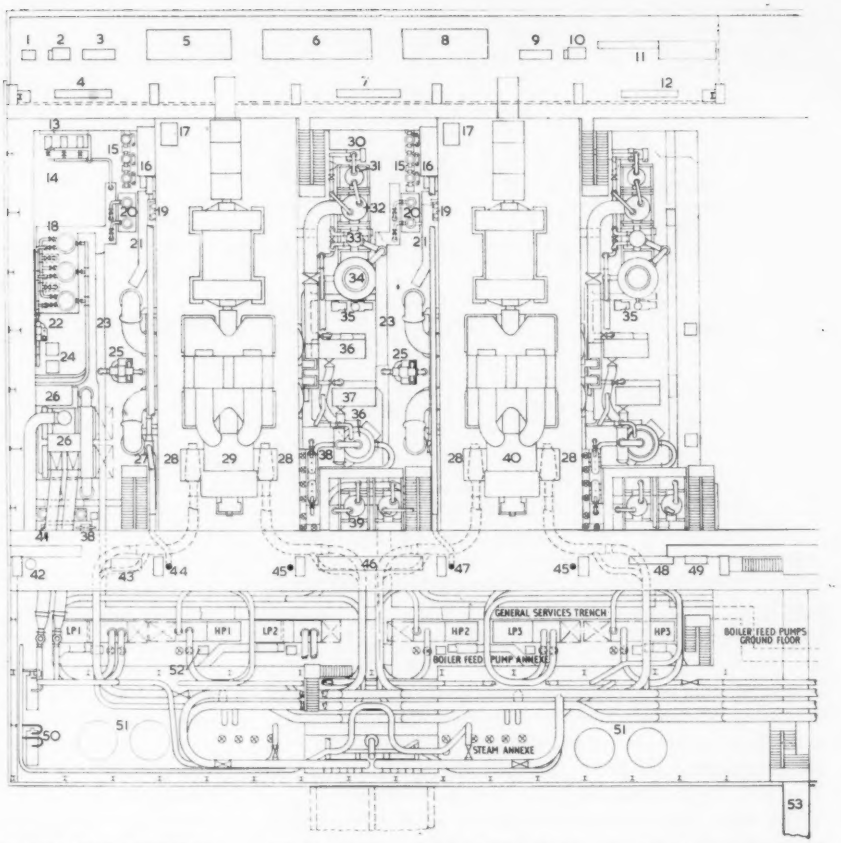
TURBINES

Each main turbo-generator (Fig. 3) consists of a two-cylinder 1500 rev/min single line reaction type turbine driving at 142·5 MW generator and exciter. The turbo-genera-

Longitudinal section through the turbine (Fig. 3)



1 Emergency supply board; 2 Turning gear board 1; 3 Turbine unit board 1; 4 Unit board 1 control and relay panel; 5 Unit board 1; 6 Station board 1; 7 Station board 1 control and relay panel; 8 Unit board 2; 9 Turbine unit board 2; 10 Turbine gear board 2; 11 Turbine services board; 12 Unit board 2 control and relay panel; 13 Cable trench; 14 Transformer oil cooler water pumps 3-50% duty; 15 Oil coolers; 16 Oil reservoir; 17 Oil purifier; 18 Reactor 1 blower oil system water/water coolers; 19 Seal oil coolers; 20 Water/water coolers for hydrogen system; 21 Pipe trench; 22 C.W. strainer; 23 Auxiliary C.W. pipe trench; 24 Culvert inspection manholes; 25 Auxiliary C.W. strainer; 26 Dump condenser 1; 27 Atmos. exhaust valve; 28 Steam chest; 29 Turbo-generator set 1; 30 Raw water and blowdown cooler; 31 Drain cooler; 32 L.P. heater; 33 Evap. vapour condenser; 34 Unit evaporator; 35 Sludge pumps; 36 Deaereator heater; 37 Extraction pumps; 38 Air ejector; 39 H.P. heaters; 40 Turbo-generator set 2; 41 Secondary desuperheater control table; 42 Dump condenser atmos. exhaust; 43 Dump condenser panel; 44 Atmospheric exhaust set 2; 45 Surge line; 46 Turbine gaugeboard sets 1 and 2; 47 Atmos. exhaust set 2; 48 Station C.W. panel; 49 Station boiler feedwater panel; 50 Emergency boiler pumps 2-50% duty; 51 Deaereated water tanks; 52 Leak-off equipment; 53 Covered access to control building.



Plan of the turbine house (Fig. 4)

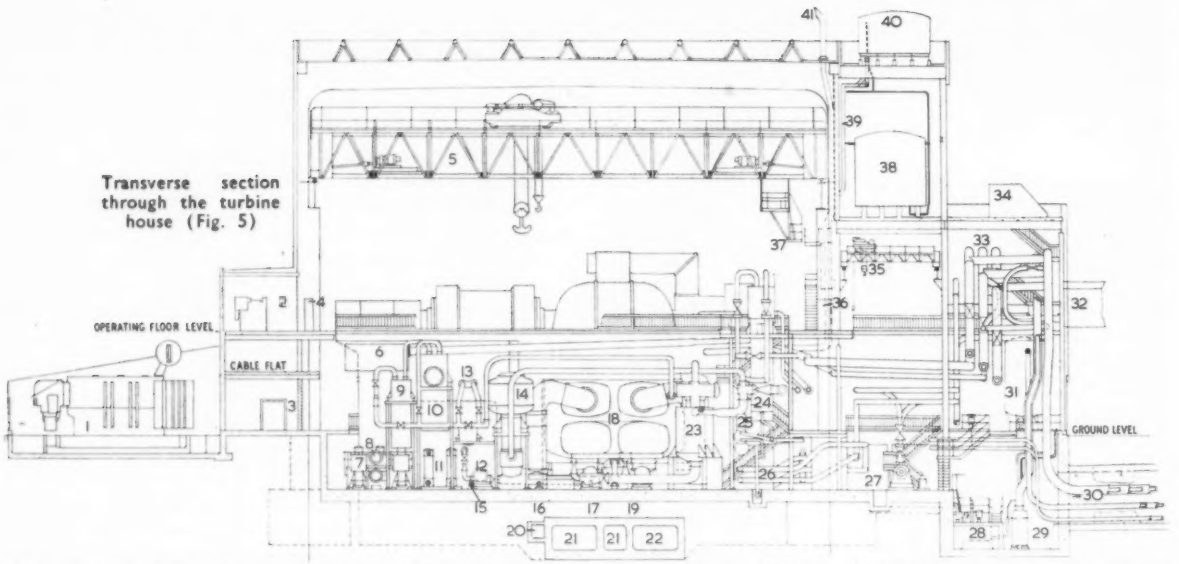
tors in addition to being designed for base load operation, incorporates all features considered essential to meet two shift operations. Steam at 550 lbf/in²a and 391°C is admitted to the high pressure turbine at the end farthest from the generator and expands through the H.P. blading before passing into the L.P. turbine. Steam is admitted on the centre of the double flow low pressure turbine and exhausts into the condenser situated below. Sectional drawings showing the layout of the turbine house are shown in Figs. 4 and 5.

Each turbine is provided with external duplicate main steam chests placed one on each side of the high pressure cylinders. Each chest contains a single seated emergency stop valve and two balanced double seated governor valves for controlling the admission of steam to the turbines. The governor valves are normally operated hydraulically under speed control. The turbines can also operate with the governor valves controlled by stop valve steam pressure. The latter operation would usually occur during starting and shutdown, the L.P. supply pressure being kept constant during normal operation by the power loop or trial system.

One of the two governor valves referred to is a by-pass valve which allows steam admission to the turbine after the first six blade pairs to increase the swallowing capacity and enable the machines to deliver full load at reduced stop valve pressures. This by-pass is incorporated in the machine to allow the turbines to operate under certain reactor transient conditions when the blower turbines have to run at 105% design speed. The single condensers are arranged for two flow operation on the water side with water boxes of the divided type, thus giving on load cleaning facilities. The condensers are designed to operate at a vacuum of 28.9 inHg at full load. Two 100% full load capacity air ejectors are provided with two duplicate full capacity motor-driven extraction pumps. The generators are designed for operating continuously at 1500 rev/min, 142.5 MW at 0.85 p.f., 13.8 kV and 30 lbf/in²a hydrogen pressure. The exciters are coupled direct to the generator and run at 1500 rev/min. They are air-cooled by a fan driven from the exciter shaft.

FEED AND STEAM SYSTEM

The four boilers associated with each reactor produce steam at two pressures. H.P. steam is provided entirely for the use of four back pressure blower turbines associated with each reactor; L.P. steam is used by the two main turbines. A ring main is provided around the reactor from which the steam tapping for each blower turbine is taken. The ring main connects to H.P. manifolds from each of the four boilers. A separate exhaust main from each blower turbine takes the steam direct to the boiler for reheating. On leaving the reheater, the steam joins the L.P. steam raised in the boiler at identical conditions. The combined steam is collected from all four boilers by three ring mains which pass down the side of the reactor into steam pipe tunnels which carry the steam mains to the turbine house. The ring mains are completed in the turbine house where tappings are taken to two main turbines. A similar ring main is repeated between the second reactor and third and fourth machines. Interconnexions between the ring mains are provided in the turbine house, the interconnexions being of one set capacity. This arrangement makes it pos-



1 Station transformer; 2 Electrical annexe; 3 Battery room; 4 Control and relay panel; 5 150/20 ton EOT Crane; 6 Turbine oil tank; 7 3-50% oil coolers; 8 Blowdown cooler and raw water heater; 9 Drain cooler; 10 L.P. heater; 11 Water/water coolers for hydrogen system; 12 2-100% duty extraction pumps; 13 Vapour condenser; 14 Evaporator; 15 Distillate pumps; 16 Sludge pumps; 17 Deaereator heater extraction pumps; 18 Main condenser; 19 Auxiliary C.W. strainer; 20 Dump outlet culvert; 21 Inlet culvert; 22 Outlet culvert; 23 Deaereator heater; 24 H.P. heaters; 25 Flash boxes; 26 Feed mains; 27 Boiler feed pumps; 28 Dirty drains sump; 29 Hot drains receiver; 30 Pipe tunnel; 31 Deaereated water tanks; 32 Personnel bridge to reactor building; 33 Steam mains; 34 Access to tank floor; 35 20 ton boiler feed pump crane; 36 Turbine gaugeboard; 37 Access platform to crane; 38 Reserve tank; 39 Gauge line; 40 Surge tank; 41 Main condenser atmospheric exhaust.

sible to operate at a range system giving maximum flexibility in choice of operating sets and reactors during maintenance. The system also allows one main turbine to be taken out of commission without impairing the uniformity of gas flow and temperature distribution in the reactor.

The dump condensers are connected into the ring mains before the take off to the main turbines is effected, making it possible for a reactor to be shut down or started up while the turbines operate on range using steam from the boilers associated with the operating reactor.

The blower turbine H.P. steam ring mains greatly increase the flexibility of operation of the system, making it possible for one blower and its associated boiler to be started up without reducing load on the other three operating boilers. Each main turbo-generator feed system incorporates surge and reserve feed tanks of combined capacity equivalent to 40 min full steam load and is designed for range operation.

Each main set feed train consists of two 100% duty extraction pumps and two 100% duty air ejectors, a drains cooler and No. 1 L.P. heater. The system includes in series a vapour condenser associated with a single effect unit evaporator. The feed then passes to a low level d.c. de-aerator with two 100% duty extraction pumps and associated de-aerated water storage tanks of 10 min full load capacity, in parallel with this unit. The extraction pumps pass feed water from the d.c. heater into an L.P. feed pump suction main. Each dump condenser delivers direct to the L.P. feed pump suction main via two 100% duty extraction pumps. Six H.P. and six L.P. boiler pumps, driven by induction motors, each of 120% full load capacity are provided. Of these, one H.P. and one L.P. pump are associated with each main turbo-generator and the remaining units provide a standby capacity, therefore, during normal operation, only four H.P. and four L.P. pumps are running. Power for four of the six sets of pumps is supplied by the main turbine auxiliary transformers; power for the standby pumps is taken from the station transformers. Four emergency boiler feed pumps are provided for reactor cooling purposes during reactor shut down. Each pair of pumps has a capacity sufficient for cooling one reactor.

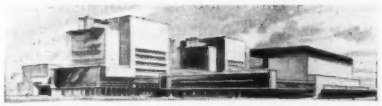
COOLING WATER SYSTEM

The C.W. pumphouse is built mainly of reinforced concrete. It is circular in shape to minimize the excavation costs. The pumphouse has been designed as an open type and, therefore, all plant and equipment is fully weatherproofed to stand marine conditions. A centre post goliath crane is provided and runs round the perimeter of the pumphouse serving the pump suction forebay and C.W. pumps, etc.

All equipment in the pumphouse has been designed for remote operation from a control panel situated in the main control room.

From the forebay, water flows through eight coarse screens into four fine band screens discharging into the pump suction chamber. The suction chamber is divided into two parts with two pump suction bellmouths in each half.

There are four horizontal centrifugal pumps each with a design duty of 88,258 gal/min at 48 ft. The pumps are driven by totally enclosed water cooled induction motors via reduction gear boxes. The discharge from the pumps is by way of 72 in mild steel pipes equipped with butterfly valves which are connected into two rectangular culverts each 10 ft by 5.5 ft. Reflux valves have not been included; in place, butterfly valves are provided equipped with automatic reflux action. Each inlet culvert passes to the turbine house at the east end and supplies water to the condensers of two main turbines. The outlet culverts pass out of the west end of the turbine house to a syphon recovery chamber. From there, the tunnel runs seawards and terminates in two vertical shafts. Marine fouling of the whole C.W. system is prevented by chlorine injection into the main intakes of the off-shore works.



DUNGENESS NUCLEAR POWER STATION

'The benefit obtained from reheat outweighs the slight increase in costs'

6. Design and construction of steam generators

by Dr W. HRYNISZAK, B.Sc., Dipl.Eng., M.I.Mech.E., Mem.A.S.M.E., Chief Research and Development Engineer, Clarke, Chapman and Company Ltd

THE THERMODYNAMIC CYCLE on which the nuclear power station is based has been explained in the preceding article and a summary of the boiler duty is given in Table 1.

The main difference between the Dungeness steam cycle and that of earlier stations at Bradwell and Berkeley is that the H.P. steam turbines drive power balanced gas circulators. The exhaust from these turbines, being at the L.P. boiler pressure level, is reheated before being mixed with the L.P. steam to drive the main turbines. With this arrangement, the higher thermal efficiency associated with a reheat cycle is obtained with a relatively small increase in length of steam piping; consequently, the benefit obtained from reheat by far outweighs the slight increase in costs.

GENERAL DESIGN POLICY

General progress in design since the first nuclear stations were built has enabled the number of boilers to be reduced to the practical minimum, consideration being given to manufacturing methods, transport to site, erection and general layout of reactor and duct work and operating requirements.

Cost considerations too, were mainly responsible for the type of circulation chosen. With the boiler duty indicated in Table 1 in mind, natural circulation seemed to offer a small gain, when compared with a system of assisted or forced circulation. Various heating surfaces were considered but a tube similar to that used for the Latina contract was selected.

TABLE 1 *Main parameters of the boilers*

Number of boilers per reactor	4
Overall dimensions of boiler shell (nominal)	23 ft 6 in i.d. x 80 ft 0 in long
Boiler tubing	Mild steel extended surface throughout. Base tube 2 in o.d. (nominal), spiral wound fin.
Circulating system	Natural
L.P. heat transfer sections	Econ. - evap.-super-heater-reheater
H.P. heat transfer sections	Econ. - evap. - superheater
L.P. superheater outlet pressure and temp.	581 lbf/in² 395°C
Reheater outlet pressure and temp.	581 lbf/in² 395°C
H.P. superheater outlet pressure and temp.	1418 lbf/in² 393°C
L.P. steam flow per boiler	281,110 lb/h
Reheater steam flow per boiler	393,340 lb/h
H.P. steam flow per boiler	400,000 lb/h
Final feed water temp.	180°C

HEAT TRANSFER AND FLOW RESISTANCE

Tubes and tube arrangement

Matrices of the tubes to be installed in the steam generators for the Dungeness station have developed along a logical path from the Bradwell elements. The basic change in the tube used has been a reduction in the root diameter and the thickness of the fins. This change had two important effects on heat transfer and flow resistance:

(1) An increase in the ratio of finned to bare tube surface area;

(2) A reduction in masking effect of the tube and hence an increase in reference flow area.

Extensive research has shown that the minimum length of tubing for boilers can be achieved by arranging the gas velocities in the transverse and diagonal areas of flow between adjacent tubes to be equal. This arrangement obviously results in minimizing the pressure drops due to acceleration and deceleration of the gas. The smallest possible tube pitch is mainly governed by manufacturing limitations, but other considerations—such as the effect of tube vibrations, etc.—may have a bearing on the important decision of how closely to arrange the tubes both in vertical and horizontal directions.

HEAT TRANSFER TEST FACILITIES

The developments which have been briefly outlined would not have been possible without extensive test facilities. The three companies concerned executed the heat transfer and flow resistance research mainly on four test rigs, two of which work at atmospheric pressure and two of which can be used at a higher pressure level. For all boiler designs, the entire gas-side operating Reynolds number could be covered.

Test rigs, working at atmospheric pressure, are mainly used for 'sorting-out' investigations, covering a wide range of different tubes and their arrangement. It is not considered that these rigs provide sufficiently accurate data for final designs since it is necessary to go to very high gas velocities to achieve the Reynolds number encountered in practice. The gas at these velocities produces aerodynamic pulsations which appear to affect the heat transfer and pressure drop correlation. The pressurized rigs are therefore being used to obtain accurate performance data on those matrices which appear promising from tests carried out at atmospheric pressure.

MECHANICAL DESIGN OF BOILERS

The elements and their supports

The tubes selected for the heating surfaces of the boilers are to be made of E.R.W. base tube with helical fins. Mild steel is used throughout, as the gas temperature is not high enough to affect adversely the physical properties of this material. Superheater and reheater tubes are to be manufactured from 'killed' steel, and the tubes in the other banks from either 'rimming' or 'killed' steel.

The boiler surface is disposed within the shell in such a way that convenient access between each tube bank and complete vertical access is provided and maximum physical area of tubing and vessel for inspection purposes is offered. At the same time, careful design has resulted in a more than 80% utilization of the cross sectional area of this vessel. Each tube bank is slung from its supporting steelwork frame and adjustable supports are provided to permit accurate installations of the tube elements. The number of penetrations has been reduced to a minimum by connecting the elements to manifolds within the shell.

Tube manipulation is being effected jointly by Messrs John Thompson Limited and Messrs Clarke, Chapman and Company Limited.

SHELLS AND THEIR ERECTION

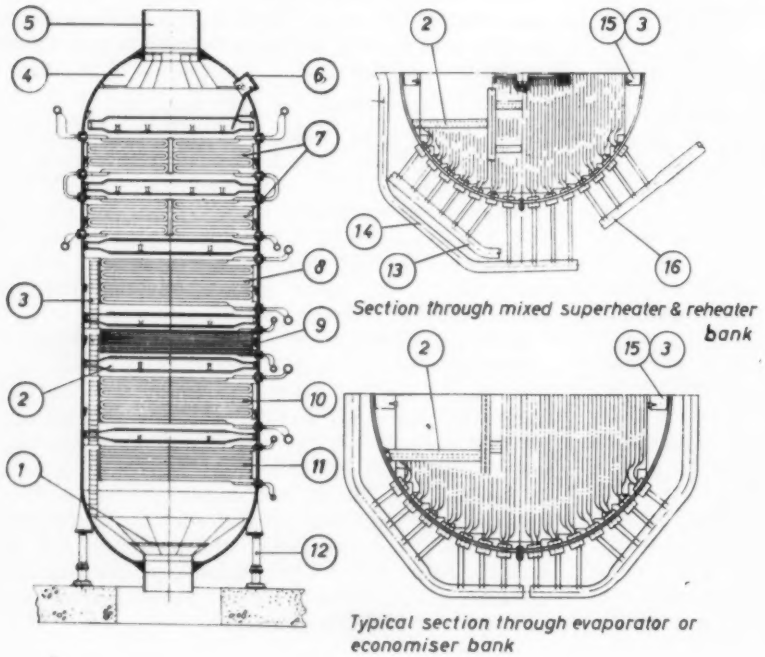
Mild steel to BSS 1501-161 grade C quality in normalized condition is also used for the manufacture of the shells of the eight boilers each of which consists of a vertical pressure vessel 23 ft 6 in inside diameter, and approximately 75 ft long (Fig. 1). The barrel plate thickness varies from $3\frac{7}{8}$ in at the upper end to $2\frac{15}{16}$ in at the lower end. Each of these boilers is closed by hemispherical ends and supported on six rocker type columns. The shells (exclusive of internals) will weigh approximately 340 tons each.

The weight and size of these shells permits manufacturing at the workshop as well as at site. Based on the experience gained at Bradwell and Berkeley, both these methods will be used for the boilers of Dungeness.

The geographical position of the fabrication shops of Messrs Head, Wrightson and Company Limited, and the site of the Dungeness Power Station, enable the four boiler shells which are being manufactured by this company to be completely fabricated in the works, launched in the river at Thornaby, and then towed to the site at Dungeness. Due to possible damage to the thermal sleeves during towing, they are protected by timber fenders bolted into position over each bank of sleeves. Preparation for launching these vessels is made at the Head, Wrightson's slipway on Teeside. The shell is run on rails to the head of the slipway, and turned through 90° by a turntable before being positioned onto the slidingway. The orthodox method of ship launching is followed, and then the boiler shells are towed to site by sea-going tugs. At site, each boiler shell is fitted with a pair of lifting arms, which, in conjunction with a goliath crane, will allow the shell to be manipulated from the horizontal position into the vertical position for installation onto the hard base.

The size of the plates used in the construction of the barrel portion of the shell is governed by the disposition of the thermal sleeves and consists of four equal plates around the circumference in six rings. The top and bottom dished ends are manufactured from petal plates $2\frac{3}{16}$ in and $1\frac{3}{4}$ in thick respectively. The barrel plates will be cold rolled to shape and automatically seam welded by the 'Electroslag' method. The hemispherical ends will be hot pressed to shape in petal segments within the normalizing range, and edges prepared for welding. Welding will be carried out using the manual metallic arc process.

Before fabrication, all plates will be subject to full ultrasonic examination and in addition, plate edges will be magnetically crack-detected. The (thinner) hemispherical end plates will be radiographed using 300 kV mobile X-ray machines. The (thicker) shell plates will be radiographed using an 18 MeV betratron unit. Then the boiler shells will be stress-relieved as complete units in a specially designed electric furnace large enough to accommodate the

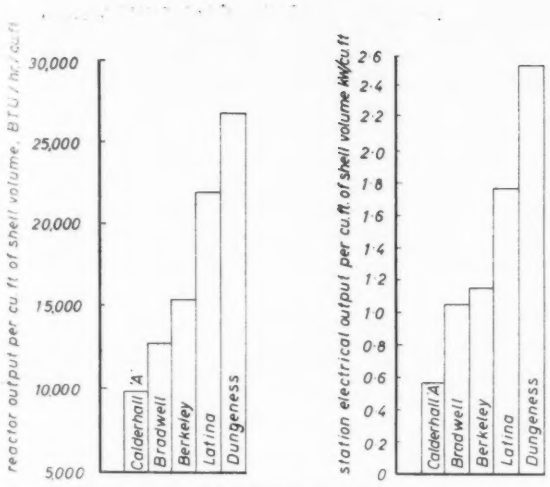


Section through mixed superheater & reheater bank

Typical section through evaporator or economiser bank

1 safety mesh; 2 tube support beams; 3 access ladders; 4 conical diffuser; 5 CO_2 inlet duct; 6 access manhole; 7 mixed superheater and reheater banks; 8 H.P. evaporator bank; 9 H.P. economizer bank; 10 L.P. evaporator bank; 11 L.T. mixed economizer bank; 12 boiler supports (rocker type columns); 13 H.P. superheated steam outlet header; 14 reheated steam outlet main; 15 access doors; 16 L.P. superheated steam outlet header.

(Left) The boiler is 175 ft high and 23 ft 6 in i.d. and operates on a dual pressure cycle; high pressure steam goes to the blower turbine drive; low pressure steam and reheated blower exhaust steam goes to the main turbine; (top right) section through mixed superheater and reheater bank; (bottom right) typical section through evaporator or economizer bank (Fig. 1)



Ratio of output with boiler shell volume (Fig. 2)

complete shells. Finally, testing will be carried out up to a pressure of 535 lbf/in^{2}g, the shell being adequately supported in the horizontal position on saddles.

The other four boiler shells manufactured by John Thompson Limited, are fabricated at site in a corrugated steel container erected on a reinforced concrete slab base.

Each ring is formed in the works in two half sections and so despatched for complete assembly at site. The thermal sleeves are welded into the plates before despatch. The hemispherical domed ends are formed by a number of petal plates which are shop welded in pairs.

The plates forming the top dome are transported into the John Thompson site workshop where they are completely fabricated as individual rings or hemispherical domes. Each section is fully radiographed or gammagraphed before being transferred into the assembly container where the vessel is completed. The pairs of plates forming the bottom dome are placed directly into the assembly container and fabricated on a prepared jig. The supporting feet, ribs and base plate are welded in position and 'A' frames fitted after magnetic crack detection of the welds. The top edge of the dome is then trimmed level and prepared for welding to the lower ring which has been formed on the Site Fabrication Shop. The assembly container is provided with a removable roof which is raised as the vertical section of the container is extended to allow the vessel to be completed section by section. While the barrel section of the vessel is being erected, the gas outlet forging and manhole are fitted in the bottom dome; this assembly procedure enables all welding other than the circumferential joints and bottom dome assembly to be completely effected in the main John Thompson Site Fabrication Shop—a fully equipped 90 ft x 40 ft shop offering facilities only usually provided at manufacturers' central works. Three containers for site vessel assembly are provided; the erection programme enables the first shell to be completed and removed from the container before assembly of the fourth shell is commenced.

After progressive erection and completion, each shell is stress-relieved, hydraulically pressure-tested and pneumatically leak-tested in the vertical position, while remaining in the assembly container. The shell is then lifted by the goliath crane and placed *in situ*. Manual welding is used throughout the site assembly of the vessel, the welds being tested by X-ray or gamma radiography using a 2000 curie cobalt-60 isotope. Protection against gamma radiation is provided during inspection of the circumferential welds within the assembly containers by a lead shield which is supported from a rotating hoist and can be located adjacent to any area of weld over the complete length of the vessel.

DRUMS AND INTEGRAL PIPEWORK

John Thompson Limited are to manufacture the drums and all pipework associated with the boilers. The boilerhouse structure will be designed to accept the loading imposed by these components. The drums are situated above the level of the boiler shells to assist natural circulation of the evaporating circuits and to minimise the size of the surrounding boilerhouse structure.

ERECTION UNDER CLEAN CONDITIONS

After each boiler shell has been lifted and set in position and the internal surfaces have passed inspection, gas seals are fitted in each of the gas ducts adjacent to the shell. The clean house reception bay, changing room and air conditioning plant unit is now assembled above the boiler, at boiler shell roof level, and ducts from the air conditioning plant connected to approved points. The seals from this unit to the boiler shell are made good and the internal hoist and all other lifting components erected in position.

The installation of the tube elements has now begun. The clean elements are transported into the boiler house at ground level, in special containers, and each container is hoisted to an opening in the bottom of the reception bay at the clean house, where the container is secured and the element removed from within. The tube element is then transported into the clean house, lowered into the shell where the tubing squad manoeuvres it into position and affixes and roughly sets the permanent supports. In this way, the outer elements are installed first, working from the top of the boiler shells to the base. When all of these outer elements are completely assembled, the centre elements are installed working from the base upwards. Each bank after completion is finally set and the nuts to the supports locked.

During the whole of erection period, conditions within the shell are maintained at proper levels of humidity by the air conditioning plant. On completion, the unit is sealed and a humidity meter installed in each shell so that a constant check can be maintained until the gas space forms an integral part of the reactor pressure circuit.

SUMMARY

The boilers of a nuclear power station provide the link between the heat producing gas-cooled reactor and the power producing steam turbines. Quite often, the importance of the heat exchangers, in connexion with the performance of thermal power stations, is overlooked perhaps because they look so simple and even unattractive when compared with the other components of such a station. Nevertheless, the heat transfer and flow resistance problems encountered in such heat exchangers are very similar to the ones to be tackled in the reactor and in the turbines.

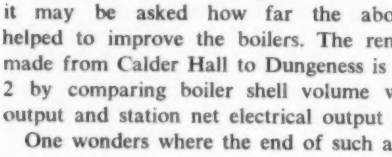
In view of future development, it is especially important to point out the close connexion between the gas-cooled reactor and the boiler. Both these components are heat

exchangers of a different kind, linked by the gas, transporting the heat produced in the reactor to the boiler, where this heat is being used to produce the working fluid for the turbines. In the proper optimization of a nuclear power plant with a gas-cooled reactor, much therefore depends on the optimization of reactor and boiler which have to be looked upon as one unit comparable to the boiler of the conventional fired power station. Looking through the description of the Dungeness boilers in this article it may be asked how far the above outlook has helped to improve the boilers. The remarkable progress made from Calder Hall to Dungeness is illustrated in Fig. 2 by comparing boiler shell volume with reactor heat output and station net electrical output respectively.

One wonders where the end of such a development lies especially in view of future nuclear power stations, where more and more compactness will be required—the familiar theme wherever heat exchangers are employed.

It seems appropriate to end this description by mentioning especially the close collaboration between the three firms involved in the design, construction and erection of the boilers. In the short time available, it was possible to combine the impressive forces of these firms in a most efficient way, giving a capacity and set-up which holds the greatest promise for the future of the boilers of gas-cooled reactors.

Acknowledgment
The author would like to thank Messrs John Thompson Limited* and Head, Wrightson and Company Limited* for their valuable contribution, and the Board of Directors of Messrs Clarke, Chapman and Company Limited for their permission to write this paper.
*Member Companies of the Nuclear Power Group.



DUNGENESS NUCLEAR POWER STATION

In spite of the greatly increased power the overall reactor building span is no greater than at Bradwell

7. Civil engineering

by A. HOUGHTON BROWN, B.Sc.(Eng.), M.I.C.E.,
Chief Civil Engineer, The Nuclear Power Group

THE CENTRAL ELECTRICITY GENERATING BOARD issued drawings of the site to be used and indicated their preference for the positions of the principal buildings on the site.

The positions were fixed for the intake and outlet of the circulating water system for condenser cooling in accordance with advice given to the Board by Sir William Halcrow and Partners based on marine surveys that had been carried out. The position of the access road onto the site and of the switching station for outgoing lines were also fixed by the Board.

The tenderer was free to develop his design within these parameters, subject to the comprehensive specification of requirements issued with the enquiry.

SITE AND INHERENT DIFFICULTIES

The site is virtually level, free of any previous development and bare of vegetation. The surface is shingle of about 2-in ring denuded of sand and is unusable by any ordinary wheeled vehicle. This leads to the difficulty of all access and working areas requiring to be surfaced but has an advantage in cleanliness and quick draining properties.

The size of the stone diminishes with depth, included sand appears and sand underlies the shingle. The surface is generally at +18.0 O.D., water table +5.0 to 10.0 O.D. varying seasonally. Shingle with some sand occurs down to about +2 O.D. below which the sands increase as the gravel decreases. The very porous nature of the upper stratum set a problem in the de-watering required for the construction of the deep foundations, culverts, etc.

The position chosen by the Board for the intake to the circulation system is 1000 ft off-shore. At this position, the predicted maximum wave height is 26 ft, corresponding to a mean hourly wind velocity of 52 miles/h. The depth of water at H.W.O.S.T. is 55 ft and spring tidal range is 22 ft. The Board require a structure in this position as a marker, for protection of the intake shafts, to carry guard screens, and to give access to the shafts and tunnels for maintenance. The provision of such a structure posed a very difficult design and construction problem.

In most other particulars, the site is a favourable one for the construction of a nuclear power station.

SOIL INVESTIGATION, DE-WATERING, FOUNDATIONS

The Board supplied the tenderer with the results of soil investigations carried out on their behalf in the form of bore-hole logs and laboratory analyses. This information was supplemented by further site tests, particularly with respect to de-watering carried out by Soil Mechanics Ltd acting for Sir Robert McAlpine & Sons. Tests were also made of the possibility of the compaction in depth of the shingle by vibratory methods but no certainty of satisfactory results could be guaranteed, particularly as the programme of construction required that the work was to be done in de-watered ground.

It was decided on the evidence that a suitable foundation level for the main reactor buildings is — 6.0 O.D. to give safe bearing to an average loading intensity of 4·7 tons/ft² with an estimated settlement of 2 in under full load and negligible subsequent progressive settlement. Further, that each reactor building foundation could be in three parts, namely, the central reactor proper with a boiler house on either side. The levels so chosen proved suitable for the plant arrangement.

The other principal building is the turbine house and the levels for this are largely dictated by optimization of the

circulating water system and construction costs. The levels for foundations arrived at in this way are found to be suitable from the foundation engineering viewpoint.

The de-watering required to establish foundations at these levels could be accomplished in several ways; the water table needing to be depressed to about – 10.0 O.D. One would be to encircle and possibly traverse the site with well-points. In this case, the de-watering would be utterly dependent on the integrity of the pumping system and even a short period break-down might be disastrous at certain stages of the construction. Partly with this in view and partly on economics, the method adopted is to encircle the whole area of the deep foundations with a girdle of steel sheet piling and pump within this from a pattern of deep wells arranged appropriately to the building outlines. The piles of the girdle are 45 ft 0 in long generally and the perimeter is some 3000 ft; the wells are 34 in number and 60 ft deep. The de-watering has been carried out and is entirely successful.

Additional de-watering to lower levels is required for the construction of the C.W. pump house and the syphon recovery chamber which go to greater depths. For these, local sheet piling to greater depths and deeper wells are to be used.

GROUPING OF BUILDINGS

The general arrangement of the buildings on the site is shown on Fig. 1 on p. 95.

The principal buildings are located in the positions indicated by the Board as their preference and the grouping is reminiscent of the Bradwell layout.

The turbine house is approximately parallel to the shoreline with the circular C.W. pump house on the same axis to the east. The discharge from the condensers exits from the west end of the turbine and the culverts turn through nearly 90° to connect to the syphon recovery chamber, from the base of which a tunnel runs to the outfall position 400 ft off-shore.

Workshops, stores, locker rooms, canteen and the administration building form a complex contiguous to the west end of the turbine house. At the request of the Board, the administration block, a three-storied building, is on the south side of this complex facing out to sea.

The two reactor buildings lie 175 ft to the north of the turbine house. They are spaced apart to accommodate a building between them containing the main control room with changing rooms underneath at ground level for reactor personnel.

The cooling ponds for irradiated fuel elements, the active effluent treatment plant, decontamination building and the laundry are grouped in an 'active' area to the north of the reactor buildings.

The switching compound for outgoing lines is to be constructed under a future separate contract and is positioned by the Board to the north of the power station site. A tunnel is provided on the N-S centre-line of the group of main buildings to run cables from the main transformers on the south of the turbine house to the switching compound.

REACTOR BUILDINGS

Each reactor building is 316 ft × 155 ft in plan with maximum dimensions above and below ground of 161 ft and 24 ft and total weight with contained plant is in the region of 95,000 tons. The buildings are at 426 ft centres. The two buildings are generally similar but there is a small degree of handling made necessary by cable runs and personnel access to the control room and changing rooms which lie between them.

The central feature is the vault for containing the pressure vessel with the associated storage voids for active components, active maintenance rooms and vertical flumes for CO_2 ducts. Throughout this region, wall thicknesses are determined by shielding requirements rather than structural considerations.

The vault for the reactor pressure vessel is 68 ft 6 in inside diameter and 84 ft 9 in high with wall thicknesses of 5 ft 6 in and 7 ft 0 in. An air cooling system is provided to keep the inner surface of the concrete at an acceptable temperature.

There is a house for two boilers on both ends of the central block and again shielding is required but of more modest dimensions.

These houses are of *in-situ* concrete construction but the ends have to be left open for boiler erection. In order to avoid *in-situ* concreting after boiler erection, these ends are closed by pre-cast panels.

On the two sides of the central block are reinforced concrete framed structures to provide the various rooms required for switchgear, cable ways, pipe bays, control plant, ventilating plant, fuel storage, etc. There are ten floors on one face and seven on the other.

TURBINE HOUSE

The turbine house is 180 ft × 390 ft in plan with maximum dimensions above and below ground of 83 ft and 27 ft. It houses four turbo-alternator sets with spindles set transversely at 70 ft centres. The framing is in structural steel of portal design for the main bay, which is equipped with overhead cranes of 113 ft span. On the south side, there is an electrical annexe and on the north a bay for steam pipes, and storage and surge tanks.

The culverts for circulating water run under the basement floor and through the below ground foundations of the TA blocks. The supply is by twin culverts, one of which serves the first two sets only and the other the rest. There is a similar arrangement of the outlet culverts and all are constructed in rectangular cross-section in reinforced concrete.

THE CIRCULATING WATER SYSTEM

As stated above, the position for the intake to the circulating water system was fixed by the Board. A survey of sea bed levels had been carried out on several occasions at intervals over the last few years and the results show that there was substantial movement of level presumably associated with the known transport of shingle along the littoral from west to east. Presumably, the decision on the location of the intake was taken after review of the movements with the intention of avoiding as far as possible a position when denudation would expose the structure to increased loading or accumulation would leave insufficient depth of water for intake.

It is required that the intake is designed to feed a single tunnel but with surplus capacity to the extent that the addition of a second tunnel would give a combined capacity

adequate for a second station on the site of greater size than the original.

It was decided that the most satisfactory form for the structure at the intake is a tubular frame. Such a frame gives the minimum resistance to currents, waves and wind and, constructed in the way described below, also avoids the need for extensive temporary works in this very exposed position. Other forms of design were considered and discarded on the grounds of the great mass, and hence cost, required for stability and security and also the hazard of the lengthy construction period.

The tubular structure comprises twelve vertical legs braced together at three levels with cross bracing in some of the panels. A timber deck is provided supported on structural steel members and a permanent derrick crane is mounted on this deck for use for maintaining guard screens etc. The structure is designed for assembly in Folkestone Harbour, for floating by the use of ballast tanks and towing from there to site. It is estimated that only four days will be required to tow to site, to sink in position and to secure against storm damage by driving piles. This work will be done in the most favourable season of the year.

Twin intake shafts under this structure lead to a single intake tunnel and there is space for the installation of a second pair of shafts for the future station. The tunnel is to be driven from a working shaft on the shore adjacent to the pump house and a shield will be used working in compressed air. The tunnel is to be lined with cast iron segments with an *in situ* concrete lining to give a good surface for the waterway.

The pump house is planned to be circular and to be constructed in a steel sheet pile cofferdam in de-watered ground. It contains four circulating water pumps, four band screens and eight coarse screens, together with means for segregating sections for maintenance.

From the pump house, twin reinforced concrete culverts in monolithic construction lead to the condensers of the turbo-alternator sets ; one culvert serves sets 1 and 2 and the other sets 3 and 4. The outlet is to similar culverts leading to the syphon recovery chamber. From this chamber, a single tunnel, in the same form as the inlet, leads to the twin outlet shafts. No structure is to be provided at the outlet, only a marker for navigation.

All tunnels and culverts are so arranged that they may be shut down and dewatered for inspection and maintenance.

DUNGENESS NUCLEAR POWER STATION

The intention is to pressure test the vessel hydraulically

8. Construction programme

by E. G. W. POVEY, M.I.C.E., Group Resident Engineer, The Nuclear Power Group, Dungeness Nuclear Power Station

THE NUCLEAR POWER STATION at Dungeness is being built by what has come to be regarded as the conventional method. The reactor pressure vessels are being prefabricated on site in large sections and lifted into a reinforced concrete vault by a goliath crane. That policy having been decided the layout of the reactor buildings, the arrangement of the site generally and to a great extent the programme of the work were established.

The layout of the construction areas and temporary buildings is shown on Fig. 1. The site is divided by a concrete road which runs south from the main entrance to the shore. To the east of this road are the permanent buildings and to the west lie the bulk of the temporary works, the concrete batching plant, aggregate storage, prefabrication areas, the camp and canteen.

The track for the goliath crane runs along the north and south sides of the reactor and is continued into the temporary works area to enclose the areas for the fabrication of the pressure vessels and boilers.

CIVIL ENGINEERING WORKS

The station is sited on undulating shingle beds just west of Dungeness Point. As wheeled vehicles cannot travel over the shingle the first operation, when work started in August, 1960, was to lay down a network of roads. For this purpose temporary sleeper tracks were laid down and, from these, concrete roads were constructed.

The major problem facing the civil engineering constructors was the de-watering of the excavation for the foundation of the reactor buildings, turbine house and pumphouse. This has been successfully accomplished by surrounding the principal structures with a girdle of steel sheet piles, 45 ft long, driven to a depth of 50 ft below ground level into the less permeable sand strata. Inside this girdle wells were sunk, submersible pumps installed and piped to discharge on to the foreshore. Within this de-watered area the main excavations were done under quite dry conditions. Work on the concrete foundations is now in progress.

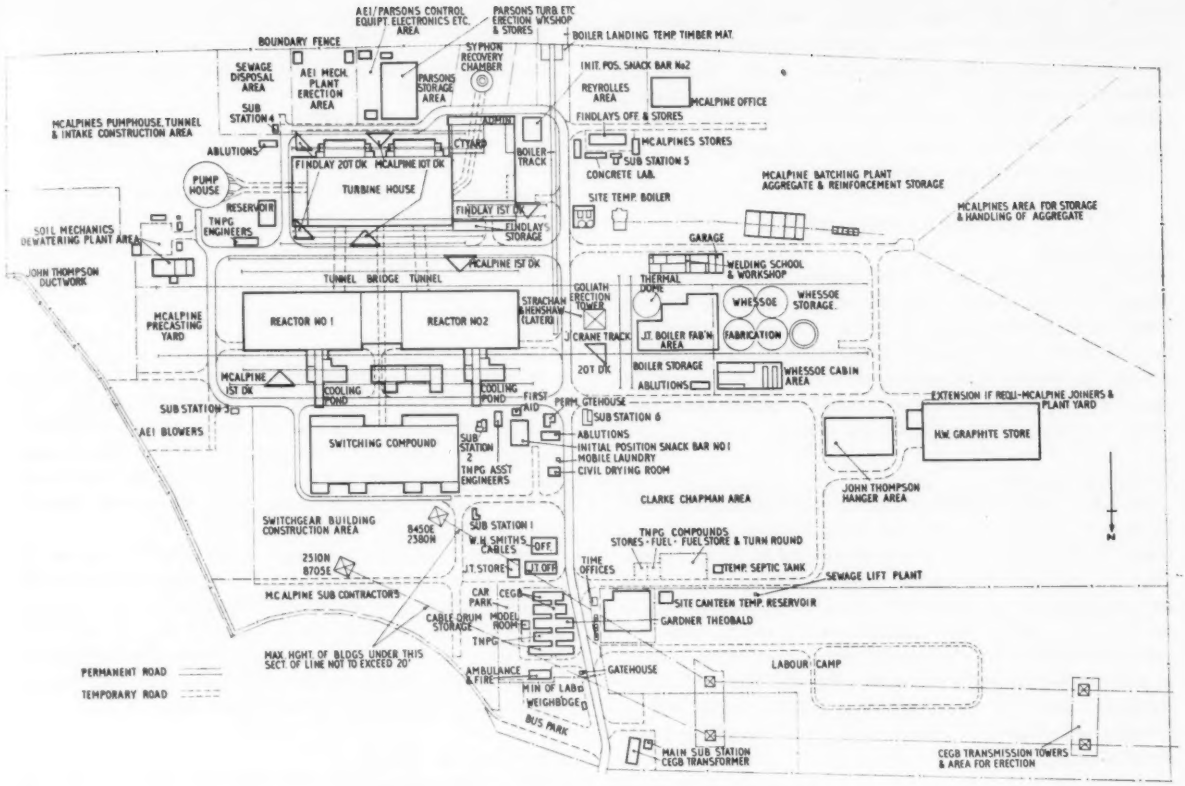
The concrete aggregates are, for the most part, being taken from the excavated material which is stocked at the west end of the site, washed, crushed, graded and fed into the main batching plant.

The buildings present no unusual problems but the cooling water system involves many constructional problems. The inlet works, which are sited some 400 yards offshore from the Point, are in an extremely exposed position.

Details of the inlet structure and of the cooling water tower are given in the civil engineering article on pp. 93, 94.

REACTOR PRESSURE VESSELS

The plates for the reactor pressure vessels will be pressed to shape and welded in pairs before despatch to site. Site



Construction areas and temporary works (Fig. 1)

fabrication of the spherical segments will take place in bin type structures with removable lids. The plates will be handled and the bin lids removed by means of a 40-ton goliath crane spanning the prefabrication area and running on the outer rails of the main 400-ton goliath crane track.

For most of the site welded seams X-rays will be used for the radiographical examination, but for the vessel support course it is proposed to employ gamma radiation using a cobalt source. The gamma radiography will take place in a bin having thick concrete walls to provide shielding.

The bottom dome will be lifted into the reactor vault and set on the support frames. An equatorial segment will then be lifted into the vault, aligned, and the latitudinal seam welded and radiographed. Meanwhile, in the prefabrication area between goliath tracks, the diagrid support for the graphite core will have been constructed. This will be lifted into the hemispherical vessel before the remaining sections of the reactor pressure vessel are lifted in and welded.

As soon as all the pressure vessel sections have been lifted into the vault, the thermal dome, which also provides the formwork to the soffit of the concrete pile cap, will be placed into position. The pressure vessel will be stress relieved and hydraulically tested followed by a pneumatic leak test.

Standpipes for the fuel loading and control rod chutes will then be welded to the stubs in the top dome of the pressure vessel. Cleaning of the interior of the vessel will follow and lining with thermal insulation will then proceed together with the completion of other internal work in readiness for graphite loading.

BOILERS

Of the eight boilers to be erected on the station, four shells are being made in the makers' works on Tees-side and the remaining four will be fabricated in workshops on site. The four built on the Tees will be towed by sea to Dungeness, hauled up the beach and placed in position by means of the goliath crane. These boiler shells will be stress relieved and tested before being brought to site.

Plates for the other four boilers will be pressed to shape and welded into half rings or segments of domes in the makers' works at Wolverhampton. They will then be transported to site by road. The assembly and matching of rings will take place in a site workshop and the rings will then be lifted into one of three steel bins with removable lids inside which the boiler shells will be assembled and welded. The welded barrel seams will be examined by means of gamma radiography and those in the domes by means of a 300 kV X-ray unit. Mobile lead shields handled by a circular runway beam will be used to provide shielding during radiography. The boiler shells constructed on site will be hydraulically tested in the vertical position in the prefabrication area. They will then be cleaned internally before being lifted into their final position.

The boilers having been positioned, clean condition houses will be erected above them. Through these the boiler tubes, which will be cleaned and assembled in groups on site, will be introduced into the boiler vessel. Meanwhile work on the external pipework, steam drums and auxiliary equipment will be proceeding.

GAS DUCTING

The phasing of duct erection and welding is a complex

operation which has to be integrated with the programme of construction for the reactor pressure vessels, boilers, gas blowers and associated civil engineering work. Site-welded seams in the ducting will be radiographed and final cleaning will take place before connexions are opened to the boilers and reactor pressure vessels. The gas duct circuit will be pneumatically tested on completion.

OTHER COMPONENTS

Gas blowers

Installation of the gas blowers presents no unusual problems. In order to supply steam for operating the turbines which drive the blowers during circuit testing, it will be necessary to provide a temporary boiler of 100,000 lb/h capacity. As far as possible the permanent steam pipework will be used for this purpose. It is also intended to use the permanent dump condensers and cooling water system.

Graphite laying

Provision will be made for the storage of graphite on site. In this store it will be unpacked, inspected and removed in a clean vehicle to the north face of the reactor building. Several floors of this face of the reactor will be used for the collection and handling of graphite and metal components for the reactor core, under clean conditions. Changing rooms for personnel engaged on work on the reactor core will be located in the rooms designed ultimately for the storage of fuel elements. Access to the core during graphite laying will be through two of the CO_2 ducts—one for personnel and one for materials.

Control systems

The gas sampling pipework and the control instrumentation will be installed during and after the laying of the graphite core. No unusual techniques are involved in this section of the work which, it will be appreciated, is probably the most intricate part of the construction programme.

Charge face equipment

The machine which is used for all the operations of fuel charging, discharging and the control rod handling will be brought to site in sections and assembled on the charge face floor using the 20 ton ' charge hall ' crane.

Conventional plant

Once again this presents no unusual problems. All components will be brought to site by road transport.

SITE ADMINISTRATION

All the actual construction work on site is being carried out by the member companies of the Group together with some subcontractors. The role of The Nuclear Power Group on site is to co-ordinate and inspect the work of the member companies and to represent the Group in the day-to-day contact with the Central Electricity Generating Board's resident site engineer.

The Group is also providing various common services on the site such as first aid, security, fire fighting and ambulance facilities. A camp to house 800 men together with canteen and recreational facilities are provided by the civil engineering company. There is no site accommodation for families. Many men are transported daily to site by 'bus, some travelling from as far afield as the Medway towns.

Progress to date

At the present time (March, 1961) the work on site is all civil engineering and preparatory works. Despite the abnormally wet autumn and a high incidence of gale force winds the work is now well up to the programme.

Preliminary list of Contractors for Dungeness

Associated Electrical Industries Ltd
Telephone and communication cables and telecommunications equipment; control rod equipment; safety circuit equipment; essential supplies sets; b.c.d. shutdown and slow scan equipment; gas flow equipment; gas circuit instrumentation; temperature instrumentation and scanning equipment; health physics equipment; medium voltage contactor, control gear and auxiliary switchgear; batteries, chargers etc; fuel element supports and gags; neutron source; bellows unit (with C. A. Parsons); turbine-driven gas blowers and pony motors; blower house C.W. system; condensers; generators; evaporators

Sub-contractors to AEI

Colvilles Ltd
Mild steel plate for bellows units cruciforms
T. Firth and J. Brown Ltd
Forging for generator rotor
English Steel Forge and Engineering Corp. Ltd
Forging for generator rotor
John Thompson Ltd
Spherical casings for CO_2 circulators

Clarke, Chapman and Co. Ltd
(Co-ordinating engineers for the boiler plant which is being jointly supplied by John Thompson Ltd., Head, Wrightson and Co. Ltd and Clarke, Chapman and Co. Ltd)
H.P. boiler superheater and economizer tube elements; L.P. reheater tube elements; acid cleaning of boilers; internal baffles and supports; boilerhouse building steelwork; boiler erection, testing and commissioning
Sub-contractor to Clarke Chapman and Co. Ltd
Clyde, Crane and Booth Ltd
Goliath and jib crane

Alex. Findlay and Co. Ltd
Turbine house main steelwork

Head, Wrightson and Co. Ltd
Main gas storage plant; orifice plates for control rod channels; thermal column and liner tubes; lanterns for fuel elements; core structure components; four (of eight) boiler shells

Sir Robert McAlpine and Sons Ltd
Civil engineering and building work

C. A. Parsons and Co. Ltd
Bellows units (with AEI); charge/discharge standpipe thermocouple elements; dump condensers; feed heating plant; flux scanning and measuring equipment (with AEI); overall automatic control system (with AEI); pipework, valves etc for turbine house; transformers and transformers oil filtration plant
Sub-contractors to C. A. Parsons and Co. Ltd
Wm Beardmore and Co. Ltd
L.P. turbine shaft disks; L.P. shafts; cylinder centres
Clyde Alloy Steel Co.
Cylinder centres; steam chest castings
Dennystown Forge and Co. Ltd
H.P. and L.P. couplings
Dorman Long and Co. Ltd
Fabricated exhaust plates
T. Firth and J. Brown Ltd
H.P. and L.P. couplings; valve spindles; H.P. and L.P. shafts

A. Reyrolle and Co. Ltd
b.c.d. panels, cocks and solenoid valves, primary selector valves; control rod actuators; H.V. auxiliary switchgear; main control room equipment; precipitators

Strachan and Henshaw Ltd
Charge chutes, control gear and ancillary equipment; charge/discharge machines and gantries; charge hall transfer equipment; coffin cranes; pile cap cranes
Sub-contractors to Strachan and Henshaw Ltd
AEI
Motors and control gear

John Thompson Ltd
Pressure vessels for charge machines; structures for gantries

John Thompson Ltd
Diagrids, supports etc; gas ducting; thermal shielding; steam and feed pipework; CO_2 pipework; site boilers; new fuel and irradiated fuel equipment; control rod and b.c.d. standpipe assembly; manipulators and remote handling equipment; control rods; decontamination and feed water treatment plant; boiler instrumentation; four (of eight) boiler shells; H.P. and L.P. boiler steam drums; L.P. boiler tube elements; standpipe plug assemblies; absorber elements

Whessoe Ltd
Pressure vessel shells; standpipes; steel tanks

Other main contractors
Andre Rubber Co.
Rubber expansion pieces
J. Blakeborough and Sons Ltd
Gas valves
UKAEA
Graphite supply
Boving and Co. Ltd
C.W. valves
Crossley Bros Ltd
Diesel generators for de-watering system
Drysdale and Co. Ltd
C.W. pumps
Hopkinsons Ltd
By-pass gas valves
Nuclear Graphite Ltd
Graphite machining
Pyrotenax Ltd
Thermocouples
W. H. Smith and Co. (Electrical Engineering) Ltd
Thermocouple installation; lighting and electrical heating; temporary electrics

There is no control of the axial flux shape

Axial flux instability in gas-cooled power reactors

by R. I. VAUGHAN, M.A. and W. J. PICKERING, B.Sc.,
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FOR THE HIGHEST EFFICIENCY in a nuclear power plant with graphite moderated gas cooled reactors, the reactor must be run with the highest possible fuel element temperatures consistent with a satisfactory element life. It is therefore important that under full power conditions any changes in neutron flux should be quickly damped out, either by a control system or by the natural stability of the reactor. In future power stations with large graphite moderated reactors, total power and the radial and azimuthal flux shape will be regulated by automatic controllers which act to hold outlet gas temperatures in several zones individually constant (*1*). There is no control however of the axial flux shape and hence calculations must be made to evaluate its variations during certain operational procedures. In particular, it is necessary to check that the flux shape is stable during steady running.

Changes in neutron flux introduce changes in k_∞ by virtue of the dependence of k_∞ on temperatures and xenon-135 concentrations. The temperature effects are generally described in terms of fuel and moderator temperature coefficients of reactivity (*2*). The fuel temperature coefficient is negative at all stages of the life of a thermal reactor and, in the civil reactors will have a value of very roughly $-2\times10^{-5}\delta k/\text{degC}$. The moderator temperature coefficient depends on fuel irradiation and in the civil reactors will vary from negative values at zero irradiation to about $15\times10^{-5}\ \delta k/\text{degC}$ as the equilibrium condition between new fuel being loaded and old fuel extracted is approached. Thus, generally the negative fuel temperature coefficient introduces reactivity changes opposing power excursions while, with higher fuel irradiations the moderator coefficient tends to aggravate power deviations. The immediate result of an increase in neutron flux is a falling away of xenon-135 concentration since the increase in the absorption of neutrons by xenon-135 nuclei is immediate while the increase in the rate of formation of xenon-135 from iodine-135 nuclei is subject to a time lag of some hours. Since the presence of xenon-135 reduces k_∞, the tendency for a flux change to cause changes in xenon-135 concentrations of the opposite sign has a destabilizing effect on the reactor power distribution. Neutron leakage has a stabilizing effect since neutrons tend to flow from regions of high neutron density to regions of low density so counteracting any deviation in the density distribution.

A stability calculation may be performed to check that the sum of these effects is always stabilizing. The value of the positive moderator coefficient at which the steady state flux distribution is on the verge of instability is calculated and this is called the threshold value. Then the difference between the threshold value and the value of the coefficient when the reactor is at normal operating conditions is called the stability margin. The size of the stability margin reflects the stiffness of the flux shape in the face of a disturbance such as a control rod movement. This means that, with a large stability margin, excursions in flux shape which could cause over heating are strongly damped.

PHYSICAL CONCEPTS

The main physical facts, assumptions and mathematical models used in an axial stability calculation are defined as follows:

(i) Within any elementary region of the reactor core there is a free neutron flux (ϕ,n/cm²s).
(ii) The heat generated in any region of the core is proportional to the rate of fission of fissile material which, in turn, is proportional to ϕ.
(iii) Multiplication (k_∞)=number of neutrons produced by fission per neutron absorbed in all the core materials.
(iv) ϕ and k_∞ are related by the neutron diffusion equation :

$$\nabla^2\phi + \frac{k_\infty - 1}{M^2}\,\phi = 0$$

where we take M^2 (the neutron migration area) as a constant independent of position. The left hand side of the equation represents the rate at which the neutron flux will change in any region and this is put equal to zero because we are only interested in excursions developing over many minutes.

(v) For the sake of simplicity the effect of the xenon on k_∞ will be neglected and changes in k_∞ are attributed only to temperature changes and to the movement of neutron absorbing control rods. It can be shown (*3*) that a stability threshold in the presence of xenon and temperature effects is quite close to that in the presence of temperature effects alone.

(vi) The dependence of ϕ on (r, θ) is neglected and ϕ is taken to be a function only of z. This is a reasonable approximation in analysing axial stability in a typical civil power reactor where channel powers are roughly equal over a region covering about 50% of the core cross-section. The validity of this approximation is currently being investigated at Risley using large electronic computers which calculate transients for the full three-dimensional reactor.

TEMPERATURE EFFECTS

Changes in k_∞ due to temperature changes within a small region of the core are attributed to fuel temperature changes (from the Doppler coefficient of uranium-238) and moderator temperature changes (which affect the shape of the neutron density spectrum). Both of the effects are described by temperature coefficients so that the net change in k_∞ from temperature changes is*:

$$\alpha_f\, t_f + \alpha_m\, t_m$$

We take α_f and α_m to be constants independent of position; α_f can be considered to have a constant value of about -2×10^{-5} δk/degC; α_m will be affected by the rate at which new fuel is fed into the reactor but it is not likely to exceed some 15×10^{-5} δk/degC.

Now the value t_f (the local change in fuel temperature) corresponding to an excursion ϕ is compounded of a change in the coolant temperature (t_c) and of a change in the fuel to coolant temperature drop.

Thus:

$$t_f(z) = t_c(z) + \Delta T_f \cdot \frac{\phi(z)}{\Phi_0}$$

where ΔT_f is the fuel to coolant temperature drop at the core mid-height in the steady state and Φ_0 is the value of the flux at the same height, and:

$$t_c(z) = \Delta T_c \cdot \frac{\int_o^Z \phi(z)\,dz}{\int_o^H \Phi(z)\,dz}$$

where ΔT_c is the coolant temperature rise up the core.

Similarly the local change in moderator temperature,

$$t_m(z) = t_c(z) + \Delta T_m \frac{\phi(z)}{\Phi_0}$$

where ΔT_m is the moderator to coolant temperature drop at the core mid-height in the steady state.

POSSIBLE TYPES OF BEHAVIOUR

Suppose that there is a small perturbation due, for example, to a control rod being displaced and then restored to its original position. There will then be a transient variation in the flux distribution subject to the condition that total power is held constant by suitable control rod movements. The initial transient following the disturbance will then evolve into one of three forms:

(i) A steady decay in the excursion so that the neutron flux returns to its original distribution.

(ii) A constant deformation in the power distribution so that the flux settles to other than the steady state distribution.

(iii) A steadily increasing deviation from the initial power distribution. This is the unstable condition which must be avoided.

The mathematical treatment determines the condition that (ii) should hold. With the set of parameters describing a core it will generally be found that the condition for (ii) (which is a transitional state between (i) and (iii) will not hold. However, it is possible to deduce from the change in any one parameter necessary to make (ii) hold which of conditions (i) or (iii) would follow a disturbance.

MATHEMATICAL EQUATIONS

We first write down the axial component of the diffusion equation for the steady state condition

$$\frac{d^2\Phi}{dz^2} + \frac{k_\infty - 1}{M^2}\,\Phi = 0 \qquad (1)$$

where Φ is a function of z only.

Suppose during a transient a steady deviation $\phi(z)$ can exist, then the total flux distribution $=\Phi+\phi$.

The multiplication will also change; suppose when the deviation in flux is ϕ that the multiplication is $k_\infty+\delta k_\infty$. The diffusion equation is then assumed to hold in the transient

$$\therefore \frac{d^2(\Phi+\phi)}{dz^2} + \frac{k_\infty+\delta k_\infty - 1}{M^2}(\Phi+\phi) = 0 \qquad (2)$$

Subtracting equation (1) and neglecting products of deviations we obtain

$$\frac{d^2\phi}{dz^2} + \frac{k_\infty - 1}{M^2}\phi + \frac{\delta k_\infty}{M^2}\Phi = 0 \qquad (3)$$

δk_∞ is the effect on k_∞ of the changes in temperatures and any controller which may be keeping total power constant. If the effect on k_∞ of the controller is $\delta k_{\infty c}$, then from above

$$\begin{aligned}\delta k_\infty &= \alpha_f\, t_f + \alpha_m\, t_m + \delta k_{\infty c}\\ &= \alpha_f\left(t_c + \Delta T_f\,\phi/\Phi_o\right)\\ &\quad + \alpha_m\left(t_c + \Delta T_m\phi/\Phi_o\right) + \delta k_{\infty c} \qquad (4)\end{aligned}$$

where

$$t_c = \Delta T_c \frac{\int_O^Z \phi\,dz}{\int_O^H \Phi\,dz} \qquad (5)$$

There are the following boundary conditions:

(*a*) Total power remains constant i.e. $\int_O^H \phi\,dz = 0$ (6)

(*b*) The deviation in flux vanishes at the top and bottom of the extrapolated height

$\therefore \phi = 0$ at $z = 0$ (7)

$\phi = 0$ at $z = H$ (8)

*Both here and in the remainder of the article lower case symbols are used for the deviation in a variable from its steady state value and upper case symbols for the steady state values. An exception is made in the case of k_∞ where the deviation will be denoted by δk_∞.

Digital computer programmes have been developed whereby, given all the parameters except α_m the lowest value of α_m to give a non-zero solution may be found together with the solution (ϕ) itself (see *1*). This value of α_m is the critical value of the moderator temperature coefficient.

A SIMPLE SOLUTION

To demonstrate the effects the various properties of the reactor have on axial stability a simple solution will be derived for the critical value of α_m.

Suppose we represent the flux distribution by values at four points up the core, two of the points (1 and 4) corresponding to the extrapolated core boundaries ($z=0$ and $z=H$) and the other two (2 and 3) to points $\frac{3}{8}$ and $\frac{5}{8}$ up the extrapolated core height. Under all conditions the fluxes at points 1 and 4 are zero. If we denote the fluxes at points 2 and 3 by ϕ_2 and ϕ_3, then we have using a Taylor expansion:

$$\phi_3=\phi_2+\frac{H}{4}\phi_2'+\frac{H^2}{32}\phi_2'' \text{ (approx.)} \tag{9}$$

$$\phi_1=0=\phi_2-\frac{3H}{8}\phi_2'+\frac{9H^2}{128}\phi_2'' \text{ (approx.)} \tag{10}$$

where $\phi'=\frac{d\phi}{dz}$, $\phi''=\frac{d^2\phi}{dz^2}$

Eliminating ϕ_2' :

$$\phi_3=\frac{5\phi_2}{3}+\frac{5H^2}{64}\phi_2''$$

$$\therefore \phi_2''=\frac{64}{5H^2}\left(\phi_3-\frac{5}{3}\phi_2\right) \tag{11}$$

Similarly at the top of the reactor:

$$\phi_3''=\frac{64}{5H^2}\left(\phi_2-\frac{5}{3}\phi_3\right) \tag{12}$$

In the steady state

$$\frac{d^2\Phi}{dz^2}+\frac{k_\infty-1}{M^2}\Phi=0$$

therefore at points 2 and 3

$$\frac{64}{5H^2}\left(\Phi_3-\frac{5}{3}\Phi_2\right)+\frac{k_{\infty 2}-1}{M^2}\Phi_2=0$$

$$\frac{64}{5H^2}\left(\Phi_2-\frac{5}{3}\Phi_3\right)+\frac{k_{\infty 3}-1}{M^2}\Phi_3=0$$

Hence

$$\frac{k_{\infty 2}-1}{M^2}=\frac{-64}{5H^2}\left(\Phi_3/\Phi_2-\frac{5}{3}\right) \tag{13}$$

$$\frac{k_{\infty 3}-1}{M^2}=\frac{-64}{5H^2}\left(\Phi_2/\Phi_3-\frac{5}{3}\right) \tag{14}$$

Suppose $\Phi_3=a\,.\,\Phi_2$ where a is a constant.

For a symmetric steady state flux distribution $a=1$. For a flux distorted towards the bottom of the reactor by partially inserted control rods, $a<1$. We now have

$$\frac{k_{\infty 2}-1}{M^2}=\frac{64}{15H^2}(5-3a) \tag{15}$$

$$\frac{k_{\infty 3}-1}{M^2}=\frac{64}{15aH^2}(5a-3) \tag{16}$$

Suppose that there is control in the top and the bottom halves of the core and this acts to give $\delta k_{\infty c2}$ at point 2 and $\delta k_{\infty c3}$ at point 3. Equation (4) for point 2 reads $\delta k_{\infty 2}=(\alpha_f+\alpha_m)\,t_{c2}+(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\,\phi_2/\Phi_0+\delta k_{\infty c2}$ where according to equation (5)

$$t_{c2}=\Delta T_c\frac{\phi_2\frac{H}{2}}{\left(\Phi_2+\Phi_3\right)\frac{H}{2}}=\frac{\Delta T_c\,\phi_2}{(1+a)\Phi_2}$$

and $\Phi_0=\frac{1}{2}(\Phi_2+\Phi_3)=\frac{1}{2}(1+a)\,\Phi_2$

$$\therefore \delta k_{\infty 2}=(\alpha_f+\alpha_m)\frac{\Delta T_c\phi_2}{(1+a)\Phi_2}+(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\frac{2\phi_2}{(1+a)\Phi_2}+\delta k_{\infty c2} \tag{17}$$

Similarly

$$\delta k_{\infty 3}=(\alpha_f+\alpha_m)\frac{\Delta T_c(\phi_2+\phi_3)}{(1+a)\Phi_2}+(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\frac{2\phi_3}{(1+a)\Phi_2}+\delta k_{\infty c3} \tag{18}$$

and to satisfy equation (6): $\phi_2+\phi_3=0$

$$\therefore \delta k_{\infty 3}=(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\frac{2\phi_3}{(1+a)\Phi_2} \tag{19}$$

Substituting from equations (11), (12) and (15) to (19) into equation (3) for the two points we have

$$\frac{64}{5H^2}\left(\phi_3-\frac{5}{3}\phi_2\right)+\frac{64}{15H^2}(5-3a)\,\phi_2+\frac{1}{M^2}\left[\frac{(\alpha_f+\alpha_m)\,\Delta T_c\phi_2+2\,(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\,\phi_2}{(1+a)}\right]+\frac{\delta k_{\infty c2}}{M^2}\Phi_2=0 \tag{20}$$

and

$$\frac{64}{5H^2}\left(\phi_2-\frac{5}{3}\phi_3\right)+\frac{64}{15aH^2}(5a-3)\phi_3+\frac{2a}{M^2}\frac{(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\phi_3}{1+a}+\frac{\delta k_{\infty c3}}{M^2}\Phi_3=0 \tag{21}$$

Since $\phi_2+\phi_3=0$

$$\frac{-64}{5H^2}(1+a)\phi_2+\frac{1}{M^2}\left[\frac{(\alpha_f+\alpha_m)\,\Delta T_c}{1+a}+\frac{2}{1+a}(\alpha_f\Delta T_f+\alpha_m\Delta T_m)\right]\phi_2+\frac{\delta k_{\infty c2}}{M^2}\Phi_2=0 \tag{22}$$

and

$$\frac{-64}{5aH^2}(1+a)\,\phi_3+\frac{2}{M^2}\,\frac{(\alpha_f\Delta T_f+\alpha_m\Delta T_m)}{1+a}a\phi_3+\frac{\delta k_{\infty c3}\Phi_3}{M^2}=0 \tag{23}$$

For control in the top half, $\delta k_{\infty c2}=0$ and from equation (22) for a non-zero solution:

$$\alpha_m=\frac{64M^2(1+a)^2/5H^2-\alpha_f\left[\Delta T_c+2\,\Delta T_f\right]}{\Delta T_c+2\Delta T_m} \tag{24}$$

this is the critical value of α_m

For control in the bottom half, $\delta k_{\infty c_3}=0$, and from equation (23)

$$\alpha_m=\frac{32M^2(1+a)^2/5a^2H^2-\alpha_f\,\Delta T_f}{\Delta T_m} \tag{25}$$

For a typical civil power reactor, the data might read

$M^2=1000$ cm^2, $H=800$ cm, $\Delta T_c=200$ deg C, $\Delta T_m=30$deg C

$\Delta T_f=150$ deg C, $\alpha_f=-2\times10^{-5}$ δk/deg C

Consider the following cases:

1. *Control in the top half*

For $a=1$, i.e. symmetric flux shape, $\alpha_m=35\times10^{-5}\delta k$/deg C

For $a=0.75$ i.e. peak moved towards the bottom,

$\alpha_m=27\times10^{-5}\ \delta k$/deg C

For $a=1.25$ i.e. peak moved towards the top,

$\alpha_m=43\times10^{-5}\ \delta k$/deg C

2. *Control in the bottom half*

For $a=1$, $\alpha_m=143\times10^{-5}\ \delta k$/deg C

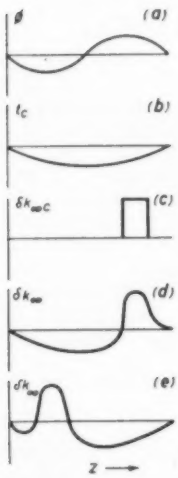
These results from the simple solution are only intended to illustrate the effect that flux shape and position of control have on the instability threshold.

The values for the symmetric flux shape can be compared with the result deduced from more complete solutions using an electronic computer: with control at 0·7 of reactor height (i.e. in top half), $\alpha_m=30\times10^{-5}\ \delta k$/degC.

This figure is seen to be lower than the corresponding value calculated by the simple solution given above.

PHYSICAL DESCRIPTION

An axial flux perturbation of the shape shown in Fig. 1*a* will give rise to perturbations in the moderator–coolant temperature difference and the fuel–coolant temperature difference, both roughly similar to shape (*a*). The perturbation of coolant temperature will be roughly proportional to $\int\phi dz$ as shown in shape (*b*). The resulting changes in moderator and fuel temperatures will each be the sum of two components, one of shape (*a*) and the other of shape (*b*). These components of the temperature changes give rise to multiplication deviations (δk_∞) of the same shape. The multiplication changes of shape (*a*) will have little effect on the reactivity of the whole reactor but those of shape (*b*) will have an overall effect. With the reactor on the verge of



Axial flux and coolant temperature perturbations (a, b); control rod effect for a position in the top half of the core (c); total multiplication shape due to contributions from axial flux and coolant temperature perturbations and controlling action in the top and bottom of the core (d, e) (Fig. 1)

axial instability the moderator temperature coefficient from the approximate solution given above will be about 25×10^{-5} δk/deg C and the fuel temperature coefficient will be about $-2\times10^{-5}\ \delta k$/deg C. Thus from the shape (*b*) contribution there will be an overall decrease in reactivity. To keep total power constant the control rods will have to add reactivity and they will do this by an outward movement. They thus increase the local multiplication over the distance they travel. For an initial control position in the top half of the core the control rod effect can be considered as a pulse as shown in Fig. 1*c*. The total distribution of k_∞ will thus be the sum of five components, two of shape (*a*) and two of shape (*b*) from fuel and moderator temperature changes and one of shape (*c*) from the controlling action. The shape of the total distribution will depend on the relative size of the five contributions. In the notation used in the mathematics above, the size of the moderator to coolant temperature difference deviation will be proportional to ΔT_m that for fuel to coolant will be proportional to ΔT_f and the change in coolant temperature shape will be proportional to ΔT_c.

Using the values assumed in the simple example given the shape of the total k_∞ distribution will be roughly as shown in Fig. 1*d*. Thus the axial flux perturbation and the resulting k_∞ perturbation augment each other and the axial flux perturbation will increase, in other words the reactor will be axially unstable.

With the control rods operating towards the bottom of the reactor however for the same value of the moderator temperature coefficient, the total multiplication will have a shape as shown in Fig. 1*e*. This shape will tend to counteract the initial flux perturbation indicating stability. Thus for the reactor to become axially unstable with control in the bottom half of the core, the moderator temperature coefficient would have to be considerably higher for the k_∞ of shape (*a*) to have a dominant effect.

CONCLUSIONS

Axial flux stability is influenced primarily by the following factors:

(i) *Temperature coefficients of reactivity:* the possibility of axial flux instability in Calder type reactors has only required comprehensive investigations because of the expectation of positive moderator temperature coefficients at higher fuel irradiations.

(ii) *The ratio the neutron migration area to the square of the core height:* the higher the value of this parameter the greater is the axial flux stability.

(iii) *Fuel and moderator to coolant temperature drops:* the fuel to coolant temperature drop has a favourable effect on stability owing to the negative fuel temperature coefficient, but the moderator to coolant temperature drop decreases stability when the moderator temperature coefficient is positive.

(iv) *The size of the coolant temperature rise through the core:* when the sum of the fuel and moderator temperature coefficients is positive this has an adverse effect on stability when total power is held constant by rods penetrating only into upper parts of the core (the coolant being assumed to flow upwards).

(v) *The axial flux distribution:* with reactivity control in the upper parts of the core only, a tendency for the flux peak to be in the upper half of the core may well have a favourable effect on stability.

Under normal operating conditions, the large Calder type reactors now under construction are not expected to need special control measures to stabilize the axial flux distribution. However, with any new reactor type or any novel mode of operation likely to influence any of the five factors listed above a careful examination of stability is required.

References

1. Vaughan, R. I., *Nuclear Engineering*, 1960, Jan.
2. Syrett, J. J., 'Nuclear Reactor Theory,' Nuclear Engineering Monographs, Temple Press, 1958.
3. Hitchcock, A. J. M. and Roberts, B. E., DEG Report 128 (R) UKAEA, 1960.

Extensive development work has gone into the novel problems associated with these experimental techniques

Irradiation techniques for fissile materials—4

by O. S. PLAIL, A.M.I.Mech.E., Group Leader, Irradiation Branch, Metallurgy Division, AERE, Harwell

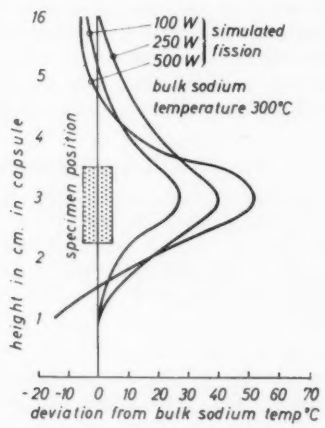
THE THIRD ARTICLE in this series dealt with the development of techniques for fissile containment and the design of heaters. This month equally important aspects of an irradiation programme; temperature measurement, instrumentation, rig safety, out-of-pile testing and laboratory simulation work are discussed.

TEMPERATURE MEASUREMENT

The effects of irradiation are largely temperature dependent and it is therefore important that specimen temperatures should be controlled accurately especially if the irradiation is taking place close to phase changes. This temperature control depends not only on the use of adequate heaters but also requires accurate temperature measurements. Therefore in parallel with the heater development considerable effort has been expended to obtain a complete understanding of the thermal conditions in the capsule. Attempts to estimate specimen temperature by methods such as heat transfer calculation, electrical analogue, etc. require very accurate knowledge of neutron flux; this is most difficult to guarantee even if an irradiation facility has been frequently used because changes in reactor loading alter the fluxes considerably. In the water-cooled rigs the practice adopted in the Windscale experiments of inserting thermocouples into the capsule as near the specimen as possible has been adhered to but with the higher heat fluxes, the larger thermal gradients make temperature measurement more difficult. Calibrated cromel-alumel thermocouples are used; these take the form of mineral insulated cable $\frac{1}{8}$ in dia. which fit into stainless steel pockets welded into the end caps (see Figs 2 and 4, *Nuclear Power*, March, pp. 101, 102). Three thermocouples per capsule are fitted; the one nearest the specimen is used for control purposes; a second is connected to an instrument which provides an overriding control; the third is spare.

For the PLUTO experiments using larger specimens, the thermocouples have been placed as close to the actual sample as possible.

Although it was realized that the thermocouples so positioned would not indicate the true surface temperature of the specimens it was considered that, as a result of out-of-pile simulation experiments coupled with calculations adequate corrections could be made. Smaller diameter thermocouples would be preferable, if these could be introduced directly into the sodium and placed either near to, or actually in, the samples. This, however, would involve considerable mechanical difficulty especially with the rather small specimens irradiated in many of these experiments

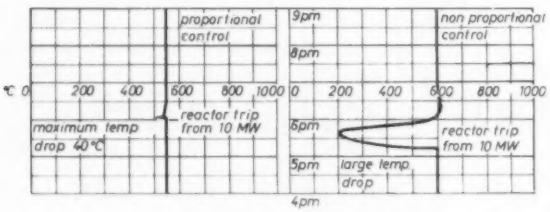


Thermal gradients in the sodium adjacent to the specimen position. Obtained from laboratory experiments using a small furnace to simulate the specimen (Fig. 6)

and could jeopardize the integrity of the assembly. However steps are being taken to overcome these disadvantages and it should be possible to obtain a direct measurement of the specimen temperature.

Considerable out-of-pile simulation work using small electrical furnaces in the place of the fissile samples has been undertaken to investigate thermal conditions in capsules identical to those in pile. Because of the extreme difficulty of

manufacturing furnaces of the same size and rating as the specimens these experiments are very hard to perform and can never simulate conditions accurately. However they do give a very large amount of data regarding temperatures and thermal gradients in the capsules and Fig. 6 illustrates typical gradient plots that have been obtained in this manner. It was as a result of such laboratory work that the control thermocouple was moved from its original position below



Comparison on the effect of a DIDO full scale power trip on specimens with and without proportional temperature control (Fig. 7)

the specimen (see Fig. 2, *Nuclear Power*, March, p. 101) to the centre of the specimen cluster (see Fig. 4, *Nuclear Power*, March, p. 102) in the later capsule design.

One of the most useful experiments performed in the course of this work has been a comparison of the relative effectiveness of the sample fission heat and the immersion heaters in raising thermocouple temperatures. This has an important bearing on the method used to estimate burnup discussed below.

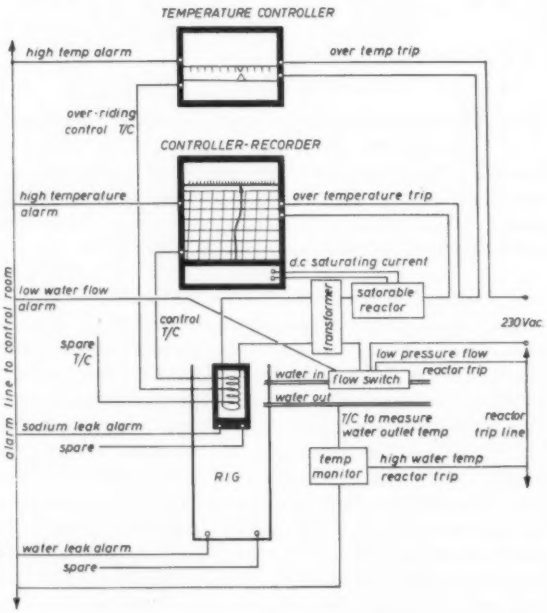
Although a very large amount of information can be obtained from these laboratory experiments they can never simulate completely accurately in-pile conditions. Therefore it has been necessary to perform short time in-pile experiments specifically to plot temperatures and thermal gradients so that temperatures in other experiments may be interpreted accurately. By using large numbers of thermocouples in a variety of positions, some actually in the specimens, and operating the reactor at various powers both with and without the heater, it has been possible to confirm the results of the out-of-pile simulation work and demonstrate the accuracy of the temperature measuring methods used.

INSTRUMENTATION

In general, there are two main requirements for the control instrumentation used with in-pile experiments. (1) It must protect the reactor from possible damage resulting from faults in the experiment. (2) It should control experimental conditions reliably. In performing the first, however, great care is needed to make certain that no needless reactor trips result and only those rig faults which could possibly result in damage to the reactor should be permitted to cause reactor trips; those faults that are considered unlikely to cause a reactor hazard, only give alarms. With these water-cooled rigs only one reactor trip function has been used, and this is associated with the coolant water flow, but as an additional safeguard a reactor trip has recently been fitted to operate should high outlet water temperature occur. To perform the second requirement, elaborate circuits are required and Fig. 7 illustrates in principle how the control system operates. It will be noted that as far as can be seen, all possible faults have been covered. In particular, the temperature control system which is so important to these experiments uses two heater trip circuits (apart from the control circuit) which come into operation at temperatures of a few degrees above that required experimentally. As will be seen later, very high temperatures are unlikely with this type of rig but with specimens frequently running close to phase changes 25°C may ruin the results. All other faults such as sodium and water leaks are arranged to give alarms.

The actual temperature control circuit by which electrical heating is introduced via the immersion heaters is an important feature. Apart from the wish to control at a pre-determined temperature it is frequently desirable to suppress thermal cycling which could result from changes in reactor power.

Therefore, a proportional control system has been used so that as reactor power alters the electrical heating changes accordingly. To eliminate the effects of large and rapid reactor power changes such as a full reactor trip, the system should be capable of increasing the electrical input very quickly to avoid a serious thermal cycle. The method used for the Windscale work i.e. a slave motor driving a variac, was too sluggish and a system using a potentiometric controller feeding a d.c. current into a saturable reactor in series with



Schematic layout of the control and alarm circuit (Fig. 8)

the furnace was installed. This system has given good control even under full reactor trip conditions i.e. where all the fission heat has been lost rapidly. Fig. 8 illustrates this and compares the temperature records of this sytem with that where there was no proportional control at a full reactor trip.

SAFETY

Instrumentation and reactor safety are intimately connected. Much can be done in the design of rigs to make them basically safe thus reducing instrumentation and the number of reactor trips that are necessary. In the rigs under discussion all hazards apart from loss of water coolant are guarded against in the design. For instance, the double canning

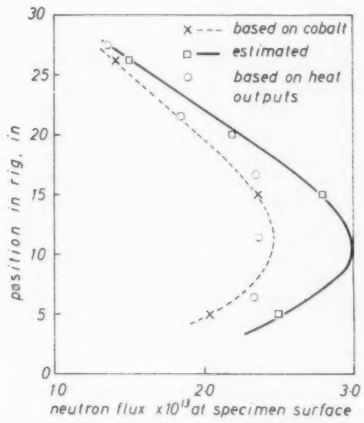
coupled with sodium and water leak detection guards against the water/sodium reaction. Again, helium gas in the thimble of the reactor guards against sudden drop in gas gap heat transfer resulting from rupture of the outer rig envelope. Perhaps the most serious hazard from fissile irradiation experiments is that of fissile material getting into the reactor itself due to a melt out from one of the capsules but in this respect these water-cooled rigs are inherently safe.

Reference to Fig 3. (*Nuclear Power*, March, p. 101) will show that at the higher temperatures the heat input increases disproportionately with temperature so that increasingly larger heat increments are needed to give similar temperature increases. This is due to expansion of the capsule closing the gaps and the effect of radiation increasing heat losses so that even under very high heat inputs, although the inner can might break and release sodium, the possibility of melting of the whole capsule is very remote. This, coupled with a fused heater circuit and limited power from the saturable reactor, leads to a very high degree of safety. In practice, high temperatures have not been a worry; sodium leaks have given good indications and there have been no water leaks.

BURNUP DETERMINATION

The measurement of burnup in fissile specimens is of great importance. Methods used include radio-chemical analysis of selected isotopes, intact γ-ray spectrometry, isotope dilution technique followed by mass spectrometer analysis, the use of flux monitors such as cobalt wires suitably placed in the capsules and the measurement of heat output. Although it is not appropriate to discuss chemical methods in this paper the techniques employed have been subject to considerable uncertainties, mainly due to sampling difficulties, although improvements are constantly being made. Cobalt monitors, however, have been used for a long period in this work and in order to interpret the results special mock-up runs are necessary at low reactor powers using manganese foils to determine the flux pattern in the rigs. Providing the flux monitors are always placed in identical positions, a fair estimate ($\pm 20\%$) of the neutron flux experienced by the specimen can be obtained. However, because of the difficulty of chemical analysis and the errors likely to be obtained using the cobalt monitors, considerable effort has been devoted to obtaining the burnup directly by measuring the heat output; the results can be quoted in the same terms as used for power reactors i.e. MWd/t.

The heat picked up from the D_2O moderator in DIDO and PLUTO makes a heat balance on these rigs meaningless but if the capsule is regarded as a calorimeter the temperature will be proportional to the heat output. Therefore, if the calibration of a capsule is known accurately the heat output may be obtained by temperature measurement alone. (This assumes that the heat transfer conditions do not alter.) As has been pointed out earlier in these articles, to a first approximation the fissile heat and the electrical heat may be regarded as being equally effective in raising the temperature of the sample. Therefore, if the immersion heater is used to calibrate the rig out-of-pile, it is possible to give the burnup rate in-pile thus: if zW are needed to obtain temperature t°C out-of-pile and yW electrical are required to maintain temperature t°C in-pile ($z-y$) W=the fissile heat xW. Because temperatures are measured centrally and fission heat is more effective by some 10% in raising the central thermal couple temperature, this result is only approximately true. From laboratory and in-pile simulation runs the relative effectiveness of the two methods of heating can be established and by applying a correction, the fissile heat rating may be obtained directly from temperature measurements. Other corrections have to be applied, such as a γ-heating allowance both from the specimen and the capsule, but these corrections are likely to be small. By integrating this heat output over the whole irradiation time, a good estimate of burnup may be obtained. So far this technique has not been perfected although it is considered that accuracy to within 5% may be obtained. Fig. 9 shows the results of an earlier burnup estimate using two different methods before later simulation work had been carried out.



Comparison of flux measurements obtained from cobalt monitors and fissile heat outputs (Fig. 9)

OUT-OF-PILE TESTING

The final laboratory test on any rig is always an out-of-pile calibration run which, apart from giving the information required to permit the above mentioned burnup calculations, simulates as nearly as possible in-pile conditions so that confidence may be established in the reliability of the rig. This is always preceeded by extremely careful checking of all components, especially thermocouples and alarm devices both before, during and after insertion into the rig. All components are thus inspected several times during construction and though this is costly, loss of a rig can lead to serious delays. Even after this step-by-step inspection and pre-irradiation calibration run when the rig is ready for insertion in the reactor, the reactor operating staff may call for some final tests. In addition, during insertion and connexion of the wiring, only one capsule is permitted to be connected at a time in order to check against its appropriate instruments. Similar standards are adopted for the specimens. It is only by applying this check and counter check that the results can be guaranteed.

CONCLUSIONS

Some idea has been given of the complex laboratory development required for irradiation experiments with fissile materials. High standards of experimental and engineering skill are called for. However, the actual irradiations are only one aspect and the next article will discuss the post irradiation examination side of this work.

Acknowledgment

The author wishes to thank Mr G. Biddle of AERE for the very considerable help given in the development of the instrumentation for these rigs.

High temperature ceramics

silicon carbide under test

AMONG THE new materials under development for working at high temperatures and in corrosive atmospheres, requiring a long life with a minimum of maintenance, is silicon nitride. Unlike conventional ceramics that lack thermal shock resistance, samples of 'Unamic' ceramics under development at Union Carbide have withstood more than 200 cycles of quenching from 1200°C into water, at 20°C. This property is due to the low coefficient of thermal expansion and inherent porosity.

Porosity helps the material to dissipate the thermal stresses set up, and as it increases so does the thermal fatigue resistance. A piece of silicon nitride with a porosity of 20% survived 55 quench cycles from 1000°C to 20°C; a specimen with a 50% porosity survived 1430 such cycles. The latter results were considerably better than the performance of some alloys in the same test.

Strength also varies with the porosity and bulk density. As the bulk density increases so does the strength; with a density of 2·5g/cc (porosity 20%) the transverse rupture strength is 9·5 tons/in² at room temperature. Strength also increases with temperature. For high density material it is greater by a third at 1200°C than at room temperature — in a sample of 2·5g/cc density, the strength increases from 9·0 tons/in² at room temperature to 13·0 at 1200°C. As for creep resistance, primary creep is reduced by an increase in the density and by making additions of silicon carbide.

Chemically, silicon nitride is very inert in most atmospheres and in contact with most non-ferrous metals. Among the few chemicals that attack the ceramic are hydrogen fluoride, some other fluorides, concentrated caustic soda solutions and fused caustic soda.

A particularly useful property is its machinability. It does not warp or shrink noticeably during the nitriding process, and a component can be shaped while still in a soft state, holding its tolerances extremely well. A 1 in dia. rod, for instance, turned to tolerances of ±0·0005 in will have the same tolerances in the finished state.

Union Carbide's 'Unamic' ceramics are being supplied as, for example, heater spools where absence of thermal fatigue is required together with accurate machining. Specimen carriers are being tested by Vickers-Armstrongs (South Marston) Ltd. in the Dounreay MTR. These components have to operate at 500-600°C in a strongly oxidizing atmosphere, and they must be machined to extremely close tolerances. Because of its resistence to molten metals, silicon nitride crucibles, thermocouple sheaths and boats are also under test.

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Radioactive waste control

Hanford's policy

The bulk of low-level wastes at the USAEC's Hanford plant come from the eight production reactors through minute amounts of impurities left in the coolant water—millions of gallons a day are used. Storage of the coolant in retaining basins before its return to the river accounts for most of the activity through decay.. Dilution of remaining amounts in the river keeps radiation levels downstream well below permissible limits.

Other low-level wastes in the form of gases given off at the separation plants are passed through silver reactor and scrubber systems, 99·9% of radioactive iodine and other particles are removed by filters. Low-level liquid waste, also from the separation plants, can normally be controlled by natural seepage at selected sites. According to Mr Irish of the US General Electric, the inventory of radioactive fission products 'stored' in the soil is decreasing by decay at a rate higher than the input flow, even for long-lived radioisotopes.

The major handling problem, however, is with high-level wastes from the separation facilities. Underground storage tanks holding a million gallons are used but these cannot be considered a final answer. This technique should be adequate for several decades, said Mr Irish, but the future probably lay in new techniques undergoing research. These include the solidification of liquids by high temperature calcination and packaging, storage in refrigerated vaults, cooling, and then ultimate removal for permanent storage.

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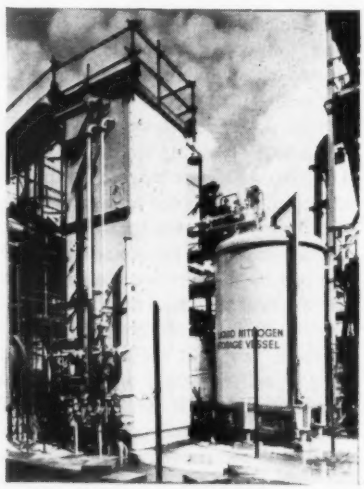
High-purity nitrogen

new on-site plant

Designed to UKAEA requirements for the supply of high-purity nitrogen at an elevated pressure, on-site plant, developed by Petrocarbon, has had a successful running period in a Production Group establishment.

Air is fractionated at low temperatures in a single column at 100 lb/in² and the nitrogen produced is delivered direct to the user at this pressure. Contamination caused by compression of the product in the earlier types of plant is thus eliminated. Although purity is normally 99·99%, still purer gas can be supplied, if required. The air, compressed to 110 lb/in², passes through the purification



For emergency storage and to cover short periods of peak demand, up to 10% of the nitrogen can be delivered as liquid to the large vacuum-powder insulated storage tank, shown here with the cold box

system and the heat exchangers directly to the column without expansion. The low temperatures are maintained by expanding a part of the compressed air, after its passage through the column, in a turbine of novel design rotating on air bearings at 60,000 rev/min.

The capacity of the present series of plant range from 4000 to 40,000 Nft³/hr of nitrogen, but larger units can be provided. If no nitrogen is consumed, the plant will 'tick-over' with the minimum consumption of power and will automatically come on stream again when consumption is resumed. If the demand at any moment exceeds the productive capacity of the plant, and if, as a result, the pressure in the user's supply line tends to fall, liquid nitrogen from the storage vessel is automatically discharged and vaporized to restore the pressure to normal and to permit an increased offtake.

Should the purity of the product fall below the desired value, production ceases automatically, thus preventing impure nitrogen from entering the supply line. The plant then runs on total reflux until the purity is restored.

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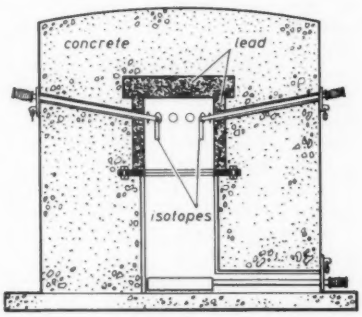
Radioisotope storage

multi-source container

As an alternative to using separate lead containers, when a large number of sources has to be stored, the South African Bureau of Standards has designed a container that houses 14 isotopes, in sealed capsules.



In this multi-source storage container a barytes aggregate was used with a density of 3·5

A hinged joint prevents the rays from being emitted along the path of entry — when the rod holding the source is pulled back, the isotope is pulled into the horizontal position and slides out easily. The sealed source is then screwed into a lead container, ready for use. Provision has been made for all the cobalt-60 likely to be required by the Bureau.

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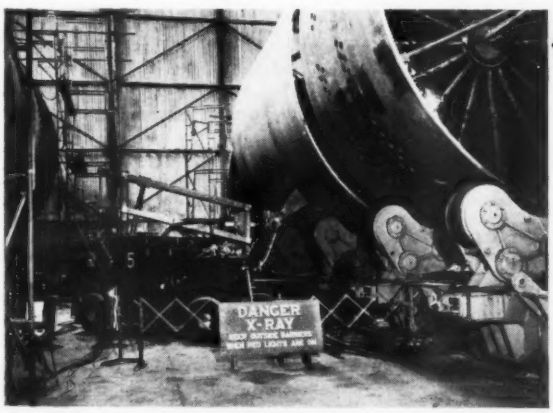
Research in Italy

industry's large part

The Montecatini Group in Italy, already one of the biggest industrial combines in Europe, relies to a very large extent on its own research facilities. Predominant in the mining and chemical industries, it owns 174 productive units and employs 60,000 persons. It produces noteworthy quantities of aluminium, zinc and their



WELDING INSPECTION AT HUNTERSTON Five Pantak X-ray units of 400kVP capacity are being used to check the welds of Hunterston's reactor vessels. Exposure time for a 3 in thick weld is 7 min, using Kodak D film and lead screens. Extensive lead shielding within the tube enables other routine work nearby to continue

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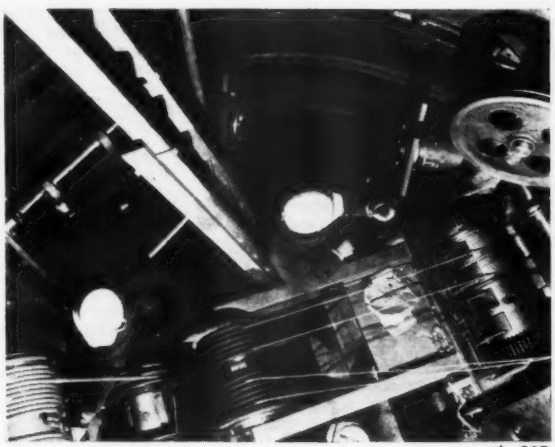

HUNTERSTON Looking down inside the first GEC Hunterston service machine. For the on-load routine maintenance of control-rod assemblies, this machine is 44 ft high, has an 11 ft i.d. and weighs 180 tons. On the left is the control rod recovery mechanism in the stowed position; on the right the control rod assembly handling mechanism, in one of its two operating positions. The other position is selected for the removal of standpipe cap and mechanism

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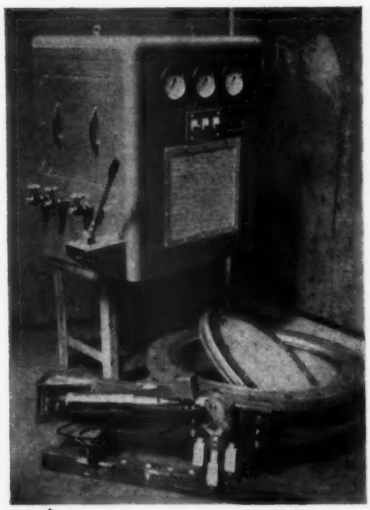

DUNGENESS COOLANT CONTROL Typical of some of the 32 Boving butterfly valves being installed at Dungeness to control the condenser water cooling system, this picture shows an automatically operated valve with a remote control cabinet in the background. Made in cast iron and stainless steel trimmed, a special neoprene lining on the internal surface prevents corrosion by sea water. Four of the 72 in dia. valves are of the automatic-closing type and combine the features of a stop valve and a non-returning valve in one unit. The others, including 72 in, 60 in, 50 in and 30 in sizes, are motor operated

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alloys, has extended its interests to the hydrocarbon industry and the field of plastics, and supplies its own power requirements by operating a system of 17 power stations.

Its scientific and applied research involves over 2000 research workers and 16 research institutes, the principal one of which is the Guido Donegani Institute for the development of applied chemistry. Through SORIN, an affiliate equally owned by Montecatini and Fiat, the Group is also active in the field of nuclear energy. The newly built Nuclear Energy Research Centre at Saluggia, which is equipped with an AMF 1 MW pool type reactor, the Avogadro 'RS-1', is particularly concerned with the application of radioisotopes in industry, considered by the Italians to be of great importance to their economy.

Research work is also being undertaken in organic moderators and coolants, in the development of electronic measuring instruments, and in such metals as beryllium, zirconium and aluminium. ★ 287

REMOTE HANDLING ROBOT Mobot Mk II manipulator designed by Hughes Aircraft can be operated from more than 100 ft away. Here it is holding a Geiger counter. Each arm has ten different movements controlled by electrical actuators, the 'hands' use soft inflated pads. The unit mounts two television cameras and microphones at the 'wrists' permit the operator to listen to the task being performed. The control console has foot pedals to regulate the speed of the robot and its arm movements; the operator watches two screens monitoring pictures of the Mobot's hand functions and manipulates toggle switches controlling the machine's shoulders, elbows, wrists, hands and grip. Other switches control the camera spotlights, focus, pan and tilt. Further switches operate the steering mechanism

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Flow measurement

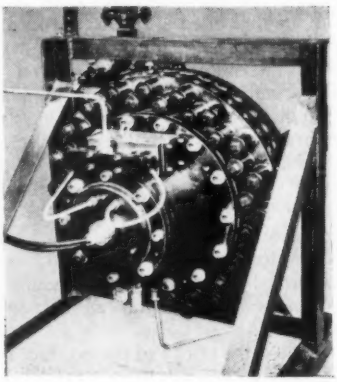
versatile control valve

A fluid flow control valve that provides a good range of flow characteristics, has been designed at the UKAEA Capenhurst Works. The device consists basically of a specially shaped seating and closure sections which can be used readily with certain existing commercial valve bodies.

Flow adjustment is provided by a movable shutter over the spaces between the tongues on the closure section. This shutter normally rotates but it can be made to slide axially, in which case the choice is available of having closed ports during the earlier part of the travel of the closure section, or of having a constant flow rate during the latter part of the travel.

The axially moving closure section is carried by a valve spindle, the gland being made leak-tight by use of flexible metal bellows sealed at one end to the valve body and at the other end to a disk integral with the valve spindle. ★ 289

SELECTOR VALVE FOR TRAWSFYNYDD Plessey have developed this 40-way selector valve for the burst fuel element detection system at Trawsfynydd. The entire driving mechanism is grouped in a serviceable sub-assembly that can be removed and replaced in around 20 min. A special ratchet indexing mechanism ensures positive and accurate location, and as a result of contained pneumatic operation, an external driving shaft is unnecessary



★ 290

IN BRIEF

PULSED ACCELERATOR Bursts of positive ions mμs long, for use in timing and studying nuclear events, are possible with the pulsed ion linear accelerator, PILAC, developed by High Voltage. It consists of a 3MeV Van de Graaff positive ion accelerator, equipped with a pre-acceleration pulsing system and a post-acceleration time compression magnet. ★ 291

MANIPULATORS FOR ROCKETS General Mills mechanical arms are being adapted for the remote handling of rocket propellants. Model 150 will supply the precise control; attached to the telescoping section of Model 100, it supplies the rectilinear motions and the capacity for lifting and carrying up to 200 lb. ★ 292

RADIOACTIVITY APPLIED US Patent 2,968,722, assigned to Tracerlab, involves the super-sensitive detection and analysis of chemicals and gases by causing them to react with a radioactive compound. Extreme sensitivity and simplicity suggests potential use in air pollution studies, atmospheric and outer space measurements and industrial process control. ★ 293

HIGH TEMPERATURE TRANSISTOR Westinghouse have under development a silicon carbide transistor capable of operating to over 343°C, 140° more than existing silicon transistors, it is claimed. It has a power gain of about 60 at room temperature, a characteristic that continues up to 343°C. Further development aims at operating temperatures in excess of 500°C. ★ 294

VACUUM BRAZING A £7500 electric resistance heated furnace, under construction by Vacuum Research for the Admiralty, will maintain 1300°C in a hot zone of 2 ft × 1 ft and at a vacuum $< 10^{-4}$mmHg. It has three flexible thermocouples for the hot zone and two for the heater; continuous recording of pressure and temperature will be provided by a six-point recorder. ★ 295

URANIUM'S NEW USE Ions of trivalent uranium and of divalent samarium are the key to an IBM process that permits the continuous generation of coherent light for possible application to space communications, scientific and industrial uses. The resulting light waves emitted from two new type optical masers have a sharply defined frequency and propagate in an intense, highly directional beam. ★ 296

TESTING POTENTIOMETERS For testing the MCD20 and other precision potentiometers, Miles Electronics have designed a special linearity tester. Using a master potentiometer, the error voltage between the master and the test unit is amplified and fed to a very sensitive pen recorder. With the two potentiometers rotating in unison, a continuous linearity recording of the potentiometer under test is obtained. ★ 297

★ *For further information on any item, circle the appropriate number on the reply card facing page* 122

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

HIGH VACUUM GAUGE

cold cathode type

The new Penning-type cold cathode ionization gauge for high-vaccum work, developed by Pulsometer for portable or panel mounted application, has a range of $10^{-3} - 10^{-6}$ torr. It is specially intended for production requirements when the pressure is constantly fluctuating between atmospheric and high vacuum.

The gauge consists of a ring anode with two plate cathodes, one either side, sealed in a glass bulb connected to the vacuum system. A permanent magnet produces a magnetic field directed along the axis of the electrodes.

★ 208

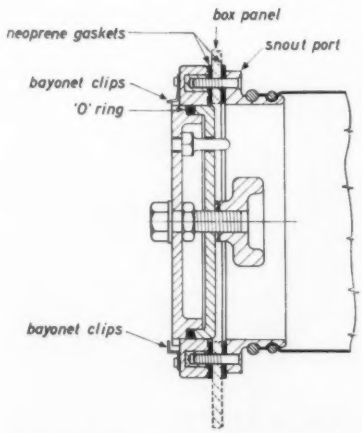
GLOVE BOX SEALS

thermally stable

A series of seals suitable for glove boxes have been developed by Dowty, based on the silicon compound SEM895, that have long life up to 175°C. They are also suitable for use in the close vicinity of reactor vessels, e.g. stand pipes and control equipment.

When the glove box is not in use, positive sealing of entrance ports is effected by the use of plug assemblies. The Dowty O-ring is used for locking as well as for sealing; When the plug is placed in position and the knurled screwhead is tightened, the two parts of the plug come together, compress the ring and force it outwards against the circular frame.

★ 209

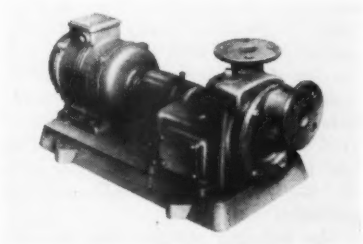


For effective sealing, the glove is stretched over the front part of the frame and is retained by a tension type clip behind which the Dowty O-ring is fitted to prevent radiation leakage between the glove and the frame

CENTRIFUGAL PUMP

self-priming

Originally designed for the chemical industry, the new self-priming Girdlestone pump, type 1AS51, has been made suitable for distillate extraction, transfer from underground tanks and the drainage of drums and sumps. The pump is basically manufactured from stainless steel and other resistant alloys, and



The new Girdlestone self-priming centrifugal pump works on the recirculating principle with a special type impeller, and has no valves or fine working clearances

mechanical shaft seals are fitted exclusively for handling most liquids including solvents, many acids and chemical solutions.

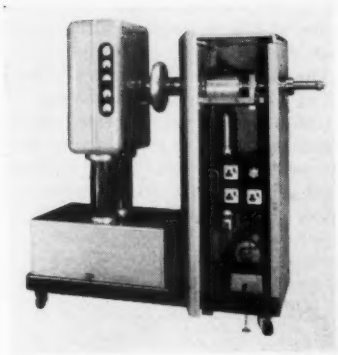
The volute priming chamber and bearing-housing with fixing feet are cast in one piece, thus reducing the number of joints to a minimum and ensuring maximum strength and rigidity. The impeller and mechanical seal may be reached by removing the volute end-cover. The impeller is capable of passing small solids in suspension and is of the open type designed for rapid priming.

★ 210

NEUTRON GENERATOR

14MeV unit

Designed to provide a source of neutrons of variable intensity and energy for use as a basic facility in nuclear physics training, 20th Century's neutron generator, type NGH 150, with a 14 MeV neutron output, offers experimental flexibility and continuous or pulse operation.



20th Century are using their neutron generator for testing fission chambers and other neutron detectors

The deuterium ions are accelerated on to a tritium target, and the neutron output under continuous operation is of the order of 10^{10} neutron/s. The unit is continuously pumped and has an accelerating potential of 150 kV. In addition to its use as a neutron generator, the instrument can be adapted to provide accelerated ion beams of deuterons or protons, and it can be used for the irradiation of samples in radioactivation analysis techniques.

★ 211

GAS MOISTURE METER

multipoint operation

New in the range of Shaw hygrometers, and used at the AWRE, Aldermaston, is a model that is being used to check the moisture content of 'dry' air in any one of eleven different locations. A moisture-sensing element is mounted in each position and indication from any sensing element can be obtained simply by moving the switch on the moisture indicator to the required position.

The presence of less than one part of water vapour in 100 million parts of dry air is immediately indicated on a separate 8 in dial. For use in air, hydrogen, nitrogen, carbon dioxide and other gases, probes are available for measurements under pressures up to 2000 lb/in².

★ 212

PORTABLE OSCILLOSCOPE

double-beam type

Solartron have improved their type CD1014 double-beam oscilloscope by providing additional trigger modes and external brightness modulation. The two identical wide-band Y amplifiers, d.c.-5 Mc/s, have a sensitivity range of 100 mV/cm to 50 V/cm with ± 5% measuring accuracy. Increased sensitivity of 1 mV/cm (at reduced bandwidth) is obtained from the built-in preamplifier preceding Y_2.

The inputs may be 'floated' with respect to the chassis to display signals isolated from earth.

The basic time-base range 1cm/μs (± 5% measuring accuracy) may be extended to 5cm/μs with the X expansion. There is direct access to the d.c. coupled X amplifier of sensitivity 0·2 V/cm to 2 V/cm. A 'bootstrap' type circuit gives a linear time-base with less

The CD1014·2 oscilloscope may be triggered internally or externally. A 30 volt bright-up pulse, derived from a separate bistable circuit, gives bright displays at all sweep speeds

than 1% variation. A square wave of ½V pk-pk- ±1% at mains frequency, is available for calibration of the time-base and Y sensitivity.

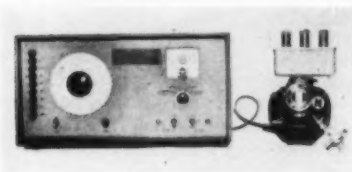
★ 213

GAS ANALYSER

high vacuum use

A residual gas analyser, designed for continuous and complete analysis of residual gases in vacuum systems, has been introduced by Consolidated Electrodynamics. Although not a complete mass spectrometer, it uses the same principle of operation to achieve precise results. Quantitative and qualitative data can be obtained by ionizing and magnetically separating the components of virtually any gas or gaseous mixture into a spectrum according to mass.

Continuous identification of the mass under analysis is provided by a self-



The analysis of residual gases in the pressure range 10^{-4} to 10^{-9} mmHg is possible with the CEC residual gas analyser

adjusting central control function that permits manual advance or retard and the presetting to start or stop at any point on the spectrum. A programmer accessory is available to automatically attenuate and control the scan of a preselected series of masses.

With a power input requirement of 3A, 60c a.c., 105-125V, the instrument is capable of a resolving power sufficient to separate adjacent peaks up to mass 20, and has the ability to measure quantities of gas, gaseous mixtures, and vapours over a mass range of m/e 2 to 80.

★ 214

LABORATORY FURNACES

high thermal stability

Shandon have introduced a range of precision laboratory furnaces that claim exceptionally high stability of temperature (±0·25°C), an interchangeable drum control for thermal cycling, and facilities for heat loss compensation at the ends of the tube. The standard range covers three models for maximum temperatures of 1050°C with tube sizes varying from 35 mm i.d. × 290 mm length to 75 mm × 700 mm, and two models for maximum temperatures of 1250°C, with tube sizes 35mm × 290mm and 60 mm × 450 mm. For operation at 1500°C two special models are also available.

The standard models may be controlled either by a thermostatic regulator or a chronograph drum control for thermal cycling, these temperature control arrangements being easily interchangeable. The drum carries a temperature chart on which the desired thermal cycling programme is marked out by a strip of thick cardboard. All models may be mounted vertically or horizontally and may be fitted with a water jacket.

★ 215

TEMPERATURE CONTROL

trip operation

Developed to UKAEA specification as part of a safety system for reactors, a temperature trip amplifier has been developed by Ultra Electronics, type AT840, that gives a continuous indication of the margin-to-trip temperature and operates warning devices at preselected high and low margins.

The unit incorporates three independent relays whose contacts are wired to sockets for connexion to the reactor safety system external to the instrument. Two of the relays are energized—one becomes de-energized at the trip temperature, and the other is de-energized at an adjustable low margin below the trip temperature. The third relay operates at

Trip temperature on the AT840 is set by a front panel control, and long-term drift under the most severe conditions is less than ±2°C

a fixed high margin below the trip temperature. An open-circuit in the reactor thermocouple, or discontinuance of the supplies to the unit, results in the de-energization of the trip and low margin alarm relays.

The output of a selected thermocouple is compared with a reference voltage from a Zener diode circuit, this reference voltage being adjustable to provide a datum temperature range of 0°-1000°C. The comparison bridge also includes optional cold junction compensation to eliminate the effects of ambient temperature variation. The difference signal is amplified in a two-stage magnetic amplifier and the output applied to the relay and indicator circuits.

★ 216

PULSE GENERATOR

portable model

Claimed to be the first of its type, a compact portable trigger generator has been produced by Winston Electronics that eliminates usual bulk and the power

Winston's type M640 pulse generator provides high voltage trigger pulses at low output impedence

consumption by using semi-conductor devices and printed circuits. Operated from two 67·5V dry batteries it can be used for testing counters, trigger and delay circuits, time bases, oscilloscope circuits, shift registers, the one-shot testing of single cycle equipment, the production of sharp high power pulses from sinusoidal and other waveforms, and for frequency division up to a factor of 20.

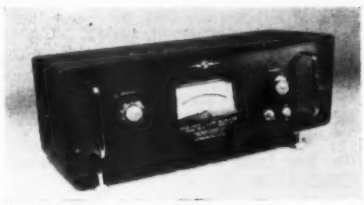
The range for free running operation is 10 pulse/s to 100 kpulse/s; for triggered operation the range is d.c. to 50 kpulse/s. Synchronization is possible from signals as low as ¼V peak amplitude with polarity the same as the required output pulse.

★ 217

GAS FLOW MONITOR

temperature compensated

Claimed as a new concept in the mass flow measurement of predetermined air or gas flow rates, the Hastings-Raydist flow monitor, has a centre reading flowmeter with variable sensitivity and range. It is adjustable for a wide range of flows at midscale by means of interchangeable flow tubes and control



Hastings' flow monitor is fully compensated for changes in temperature and rate of change of temperature

adjustments—with the K-23 flow tube of ¼ in diameter, the range at midscale can be varied to read as little as 90 cc/min (s.t.p.) or as high as 40,000 cc/min (s.t.p.); larger flow tubes up to 1in diameter extend the range to appropriately higher values.

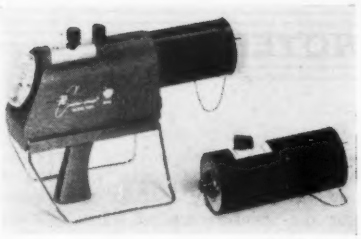
As zero flow is approached sensitivity to low flow rates increases. Pressure drop through the flow tube is eliminated and it is possible to withstand overflows and overpressures of ten times the normal range without damage. Operation is from 90-135V a.c. 60c and the electrical output available is suitable for remote indication, control, or the recording of mass flow rates.

★ 218

RADIATION MEASUREMENT

integrating ratemeter

Nuclear-Chicago have introduced a gun-type survey meter, the 2586-S, which provides both rate of dose and accumulated dose measurements. The instrument is used for monitoring beta, gamma, and X-radiation of low and medium intensity. It may also be used for measuring alpha radiation with energies as low as 4·5 MeV.



The 2586-S survey meter can be used for monitoring radiation in radioisotope techniques, for checking shipping containers and for health monitoring

The two modes of operation are effected by the interchange of the two ion chambers. The rate chamber gives measurements in three ranges: 0-25, 0-250 and 0-2500 mr/h; the integrating chamber gives accumulated measurements in the ranges: 0-0·25, 0-2·5, 0-25, 0-250 and 0-2500 mr. Energy dependence of both chambers is ± 4%.

★ 219

IN BRIEF

• **Load moving castors.** Used by the UKAEA and nuclear firms for easy movement of heavy loads are the omni-track conveyor ball transfer units made by Autoset. Load balls vary from ½ in to 4 in dia., with capacities 75 lb to 20 tons respectively. Jacking screw, prestress springing and/or shock absorbing elements can be incorporated.

★ 220

• **Protective clothing.** Miller Rayner have introduced a range of disposable paper overalls that have similar properties to cotton fabrics and are claimed to have high tensile strength and resistance against water and flame.

★ 221

• **Precision potentiometer.** Miles Electronic's new MCD potentiometer is fitted with up to 33 taps, in addition to the normal end connexions, and it has a very low starting torque, 5gcm for resistance values above 10kohm and 7gcm below 10kohm. Its dimensions are 1 in depth and $^{2}/_{32}$ in o.d.

★ 222

• **Flame-proof fabric.** Herculite 20, a new type coated nylon tarpaulin fabric of high tear strength and high fire resistance, is being used for covers in construction work involving hot sparks, etc.

★ 223

• **Silicon transistors.** Primarily for use in electronic computers, Texas Instruments have introduced the XB26 silicon epitaxial transistor and claim it will give amplification up to 200Mc/s and a switch time twice as fast as any other available silicon transistor.

★ 224

• **Tube joints.** Tubular structures for a wide variety of load bearing applications can now be made without welding, bolting, screwing or clamping. The Clinch tube joint, introduced by Access Equipment, makes a permanent union of two or more tubes of 16SWG and 1¼ in o.d., 1 in o.d. and other variations will follow.

★ 225

• **Protective clothing communications.** For use in their range of pressurized suits, Spembly have designed for the UKAEA an intercommunication system with a control console capable of supplying up to 10 slaves. Direct communication is possible both between any slave and master and between slaves. Although power supply is obtained from the mains, it is transistor regulated and can switch over to a 12V battery supply in case of mains supply failure.

★ 226

• **Floor maintenance.** Operating at 80-100 lb/in², with a power output of 0·75 bhp at 1500 rev/min, the compressed air driven Cimex Vulture scrubbing and polishing machine has been introduced to obviate fire hazard.

★ 227

• **Water cooled valve.** Three new AEI valves : type 15P12, with maximum anode dissipation of 0·6kW and maximum r.f. power output of 2·5kW ; and types 16P12 and 16P13, both with maximum anode dissipation of 3kW and maximum r.f. power output of 7·5kW, are cooled by a spiral copper water tube attached directly to the anode.

★ 228

• **Potentiometric recorder.** Designed to measure and record small d.c. outputs from thermocouples and transducers, a new Smiths' instrument uses a variable current force balance unit that eliminates the need for a slide wire and provides infinite resolution.

★ 229

• **Timing unit.** Designed primarily to operate with the 1009 series of scaling units, Dynatron have introduced a type N108 timing unit that has a maximum time store of 100,000s and a maximum count store of 1 million counts. It allows the 1009 scaler to be used at 200kc/s per second.

★ 230

• **Liquified gases.** A new plant for producing liquid hydrogen and/or liquid helium is now in service with BOC's Scientific Division to meet a rising demand.

★ 231

• **Corrosion protection.** In our January issue we described Secomastic's new Galvafroid-Micanox protective system as being a zinc-free compound mixture. This should have read ' a zinc rich compound '.

★ 232

★ *For further information on any item, circle the appropriate number on the reply card facing page 122.*

STUDENTS' NOTEBOOK

GROUNDWORK—Instruments

Why is a knowledge of electronic circuitry necessary to users of nucleonic instruments?

Electronic instruments are used in every phase of the nuclear industry, in reactor operation, fuel processing, radioisotope techniques, radiochemistry, health monitoring, and nuclear physics research. The range of user varies widely—management, technicians, engineers, chemists and nuclear physicists. Whilst some workers in the field, particularly those engaged in research, may find it necessary to develop certain special items of equipment a good deal of standardization has been reached. The design of this equipment is a highly specialized art but every user must know enough about it to select the correct instrument for the job, to use it to its best advantage and, most important, know its limitations. This means he must have some grasp of the fundamentals of electronics and a knowledge of the rather specialized circuits employed in nuclear measurement. Hence training is important.

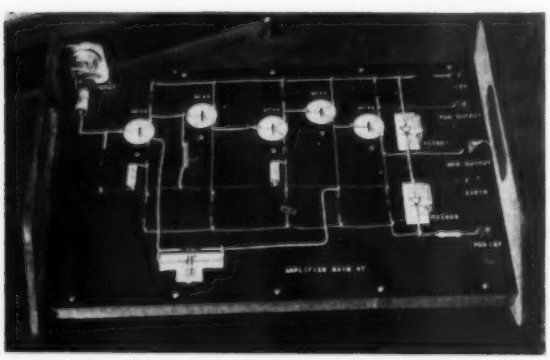
The circuits employed include some means for the amplification of the signal from the detector, involving a pulse shaper and a pulse amplifier which certainly must be stable and also linear if energy, and therefore pulse height, measurements are to be made. Alternatively, if only the integrated effect of radiation on the detector is required then a d.c. amplifier capable of current measurements as low as 10^{-13} A is required. Circuits are needed for the measurement of the rate of arrival either by straightforward counting and recording of individual events or by integration as in the ratemeter. Such circuits are usually preceded by an amplitude discriminator to reject unwanted pulses, e.g., noise, or to measure one type of radiation in the presence of another type. A very important class of circuit is that devoted to the measurement of the pulse amplitude spectrum from a detector for in this way the energy distribution of the incident radiation is obtained. Finally, circuits are needed for the measurement of time relationships between nuclear events. These range from the simple coincidence circuit to the complicated time spectrometers required for time of flight neutron spectrometers.

Teaching aids

Although the complete circuits used may be quite complex, they can be reduced to a number of relatively simple basic circuits. At the Borough Polytechnic, the method of approach to the training problem has been the construction of a number of demonstration panels each intended to illustrate a particular basic circuit. The student is provided with such a panel together with certain ancillary equipment, e.g., a pulse generator, a measuring oscilloscope, a video oscillator, a valve voltmeter, power supply, etc. He then carries out a series of measurements intended to facilitate his understanding of the circuit operation and to make clear the important features.

The two dozen or so circuits in use at present fall mainly into two categories. First, there are a group of circuits which are fundamental to all electronics although, naturally, the treatment emphasizes their nuclear applications. Such circuits include single stage amplifiers, both transistor and thermionic, cathode coupled amplifiers, cathode followers and simple trigger circuits. There is also a panel that illustrates the fundamentals of pulse shaping and includes RC differentiating and integrating circuits.

The second group of circuits used are those which are fairly special to nuclear instrumentation. A number of panels have been designed to illustrate the different types of counting circuits including bistable circuits, both transistor and thermionic, and those employing special counting tubes: the Dekatron, the ribbon decade tube and the trochotron. In addition, a panel including the diode pump, the basis of the usual ratemeter circuit, is used. There are also circuits for pulse amplification illustrating the application of negative feedback in obtaining linearity and stability. The latter principle is also used for a d.c. amplifier for small current measurement, employing an electrometer valve. Finally, circuits showing the principles of amplitude and time discrimination are provided to illustrate the operation of pulse analysers.



The transistor linear amplifier demonstration panel in use at the Borough Polytechnic. Students make measurements using a video oscillator and pulse generator, and make adjustments on negative feedback to give optimum operating conditions. This type of circuit is suitable for use with a BF_3 proportional counter for neutron flux measurement

NEWS

• To help plan a new chemical engineering course at Nottingham University, Corporate and Graduate Members of the Institution of Chemical Engineers were sent a questionnaire to find out how frequently the various academic subjects were used in day-to-day practice. Analysis of the replies suggests that Management, Economics and Report Writing occupied from a quarter to a third of a chemical engineer's time, perhaps more.

FILMS

• **European Conference** Some 40 foreign delegates representing Unesco and other international bodies, and UK delegates, all concerned with audio-visual media, met recently in London to discuss the problems of exchange and use of cultural, educational and scientific films throughout Europe.

• *High speed aluminium welding.* 2 reels, 16 minutes (in colour). Free hire from the Central Film Library. (Aluminium Co. of Canada)

• *Chemical booby-traps.* 1 reel, 11 minutes—safe handling of chemicals (in colour). 10s. hire from the Central Film Library. (GEC, USA)

• *Production of uranium feed materials.* 3 reels, 25 minutes (in colour). £1 10s. hire from the Central Film Library. (USAEC)

• *In-pile loop tests of homogeneous reactor materials.* 3 reels, 25 minutes (in colour). £1 10s. hire from the Central Film Library. (USAEC)

• *Living with radiation.* 3 reels, 28 minutes (in colour). £1 10s. hire from the Central Film Library. (USAEC)

• *Pipeline construction.* 3 reels, 29 minutes (in colour). Free hire from the Central Film Library. (William Press & Son)

UK Courses

Leicester College of Technology and Commerce Radiochemistry: 1¼ year post-graduate diploma course, April and October. Fee: £50. First five weeks consists of a general isotope course. Accepted by DSIR as suitable for the tenure of its Advanced Course Studentships.

Imperial College, London Nuclear Technology (chemical), 1961–62 post-graduate course. Applications by 1st June. Fee: £64. Accepted by DSIR as suitable for the tenure of its Advanced Course Studentships.

Battersea College of Technology, London Vacation courses: Applications of Electron diffraction—13th–14th April, Fee: £5 5s.; Fracture of Metals—11th–14th April, Fee: £10 10s.

Points from Papers

reports, meetings, conferences

MELTDOWN CONFIGURATIONS

It has been postulated that a core meltdown in a fast reactor would produce a superprompt critical configuration and the energy release from such a situation has been calculated for one-dimensional geometry. The paper describes assemblies where, because of the non-uniform fuel distribution, it might be possible for the power distribution to move fuel by expansion to positions of higher reactivity worth. Calculations of the size of the explosion for such a situation have been programmed for the two-dimensional geometry using flux and reactivity worth as input data. Accurate knowledge of reactivity worths and fission rates were not available and measurements were carried out on two configurations in the ZPR-III. The authors conclude that in the geometries studied fuel expansion would not give rise to any greater alarm than in the one-dimensional geometry case and also that as the threshold energy for pressure buildup is lower in the non-uniform fuel distribution case the explosion would be smaller than in the one-dimensional geometry case.

Studies of two fast reactor critical assemblies based on meltdown configurations. W. Gemmell. Argonne National Laboratory. Paper presented to the ANS meeting Dec. 1960. Available from *Nuclear Power*.

METALLIC HYDRIDE FUEL CELL

Certain metals and hydrogen form metallic hydrides producing electrical power and discharging waste heat. Thermal heat from a reactor can be used to dissociate the hydride in a regenerator. A completely closed system can be operated with heat absorbed in the regenerator and rejected from the cell; the metal, hydrogen and metal hydride is continuously circulated between the cell and the regenerator. Two methods of dissociation are discussed. External regeneration would use heat transferred from the reactor. Internal regeneration would also use reactor thermal heat but there would also be a large amount of nuclear dissociation due to neutron collisions.

Fuel cells based on nuclear reactors. T. A. Ciarlariello, R. C. Werner. MSA Research Corporation. **Report MSAR 60-115.** 17 pp. Paper presented to the AIChE symposium on fuel cells, Dec. 1960. Available from *Nuclear Power*.

k_{excess} MEASUREMENTS

This paper, presented to the ANS annual meeting Dec. 1960, compares two methods of measuring k_{excess}. The first is the so-called conventional method where with a uniform pattern of control rods, all equally withdrawn, a single rod is moved and the rod shape curve measured. Each 'typical' rod is calibrated by measuring its entire worth. The sum of the worths together with the control rod shape is used to determine k_{excess}. The second method eliminates the flux perturbations in the direction of control rod travel by inserting an amount of poison in each longitudinal increment of the reactor which is proportional to the amount of fuel in that increment. The author concludes that this second 'unperturbed' method is to be recommended as it is apparently more reliable and less time is needed to get a k_{excess} measurement.

Comparison of methods of measuring k_{excess}. J. F. Kunze. General Electric, Flight Propulsion Division. 9 pp. Available from *Nuclear Power*.

NOISE TRANSFER FUNCTION

It has been pointed out that as reactor noise is characteristic of the reactor in which it appears it should be possible to determine kinetic parameters from power noise measurements. This paper develops a theory by means of which the noise transfer function corresponding to any given kinetic model can be calculated. Reactor kinetic equations are generalized to the macrostochastic equations satisfied by the pile noise. From these the differential equations of the various correlation functions are determined and solved for the noise spectra. The case of single feedback, one-delay-group model is treated in detail.

The power noise transfer function of a reactor. M. N. Moore, Atomics International. **Report NAA-SR-4197.** 15 pp. Available from OTS $0·75 or depository library.

ATOMIC ENERGY RESEARCH

This is a special report of the US Atomic Energy Commission describing basic research carried out in the medical and biological fields and in the physical sciences.

Atomic energy research in the life and physical sciences. USAEC Special report. 175 pp. Available from OTS $1·75 or depository library.

RESEARCH HIGHLIGHTS

This is a new publication which presents in digest form an illustrated account of the US National Bureau of Standards research and measurement activities in the fiscal year 1960.

Research Highlights of the National Bureau of Standards, Annual Report 1960. National Bureau of Standards Miscellaneous Publication 237. 189 pp. Available from Superintendent of Documents, US Government Printing Office, Washington 25, D.C., $0·65.

NUCLEAR TEST GAUGE

This paper describes a subcritical assembly which is used for the relatively fast non-destructive checking of material samples. The assembly is plastic moderated and the core contains 4·2 kg of U-235 in the form of uranium foil about 93% enriched. Samples inserted into the assembly effect the multiplication and the resultant change in neutron level is measured. The gauge is also useful as a convenient and stable source for checking low level radiation detection instruments or for activating foils. It has been used for the determination of uranium loading in some specialized ceramic fuel elements, measurement of the cross-section of moderator materials and the evaluation of the relative worth of poison materials.

A description of a nuclear test gauge. Harold E. Brown. General Electric, Flight Propulsion Division. Paper presented to the ANS meeting Dec. 1960. 11 pp. Available from *Nuclear Power*.

SURFACE BARRIER DETECTORS

Success with surface barrier gold-germanium detectors has indicated that they would be very useful devices for measurements on the fission process. The fabrication of such devices, particularly gold-silicon ones and their use in detecting and measuring fission fragments is described in this report. The main features of this work are the use of detectors with larger areas to achieve the high counting rates needed for work with neutrons and the mounting of the detectors so that the amount of scattering material is minimized. This last is especially important when measuring the energy dependence of fission cross-section in the resonance region

Fission measurements with surface barrier solid state ionization chambers. Edward Melkonian. AERE Harwell. **Report AERE R 3524.** 36 pp. Available from HMSO *5s 6d*.

BERYLLIUM PURIFICATION

Work is going on in the UK, the USSR, USA and in France for the purification of commercial beryllium metal to an ultimate standard of ultra-high purity. At the AERE, Harwell, gram quantities have been handled successfully by a distillation process involving condensation in a heated tube, the temperature of which was graduated from 1300°C at the bottom to 900°C at the top. Further work needs to be carried out however to obtain more information on the distribution of carbon, oxygen, chlorine and fluorine and on the behaviour of alternative materials of containment.

The purification of beryllium metal by a distillation process. E. W. Hooper and N. J. Keen. AERE Harwell. **Report AERE R3321.** 20 pp. Available from HMSO.

New Reports

A programme for the evaluation of resonance escape probabilities and self shielding factors in hydrogen moderated lattices. Mrs A. J. Taylor. AERE Harwell. **Report AERE R3364.** 18 pp. Available from HMSO *3s*

Assay of strontium-90 in human bone in the United Kingdom. Further results for 1959. Medical Research Council. **Monitoring Report Series No. 1.** 18 pp. Available from HMSO *1s 6d*

The saturation characteristics of mean-current fission ionisation chambers. J. A. Dennis and W. R. Loosemore. AERE Harwell. **Report AERE M566.** 22 pp. Available from HMSO *3s 6d*

Transistors in experimental work. F. M. Russell. AERE Harwell. **Report AERE M650.** 33 pp. Available from HMSO *6s*

Nanosecond 100 ohm delay system with remote control facilities. A. K. Barlow and J. F. Gibbs. AERE Harwell. **Report AERE M720.** 77 pp. Available from HMSO *2s 6d*

The solid-state surface barrier charged particle detector. G. Dearnaley and A. B. Whitehead. AERE Harwell. **Report AERE R3437.** 32 pp. Available from HMSO *5s 6d*

Cross Section by GRACCHUS

I DON'T know why the reorganisation of the AEA should take effect from such a date as April 1 but one has to welcome the forming of a Reactor Group in which 'the work of designing and developing nuclear reactors will be concentrated to the greatest possible extent'. Though Aldermaston have just got away with it—through the announcement of VERA, a zero-energy fast reactor, coming into operation—it was about time that the far-flung fast breeder programme with FRED at Dounreay, VERA at AWRE and ZEBRA at Winfrith, was brought together. All this will, of course, mean a new game of musical chairs at Risley where Development and Engineering Group is to be rent into the Reactor Group and Engineering Group. Perhaps when the dust has died down and there has been a slowing up in the recent comings and goings at Charles II Street, we will have less of these scattered empires.

Coming at about the same time as these changes were announced, were the AEA estimates for 1961-62. These show a drop of £15.2 million, from £98.3 million in 1960-61 to £78.1 million. At first glance, one would think that an economy drive was under way. However, the reduction is said to be due to capital programme reductions, less money being spent on uranium purchases and more income from sales of civil fuel elements and radio-isotopes. One has the suspicion, however, that the number of staff may be looked at closely.

MY REFERENCE to VERA at Aldermaston makes me wonder why the AEA is so fond of hiding its achievements from the public. It seems to me to be unnecessarily secretive not to have announced that VERA was being built and not to issue various progress reports before letting go with the announcement that it had come into operation. Perhaps Aldermaston think that everything being done there is still top secret. Harwell, too, are not exempt. I believe an overdue 'open house' is being planned for the near future. Perhaps then some information will be given on the experimental work on the fixation of fission products in glass and the coming pilot plant-stage which Sir John Cockcroft mentioned in January at a symposium held at Trombay. The cabal of obstructive officials who inhabit every large organization seem particularly well-entrenched in the AEA. I can't, for instance, see them letting us know about the BEPO preparations for the second Wigner release soon after Easter (or for that matter the private sweepstake based on the temperature at which the Wigner energy will be released).

THE BUILD-UP of competitors in Europe in the nuclear components field has surprised an acquaintance of mine. His complacency about the superiority of British goods and workmanship was shattered when he found that many Italian manufacturers have stocks of components of all kinds available for immediate delivery to the nuclear industry. Their prices, too, were fiercely competitive with UK products which were only available for forward delivery. The warnings have been raised in the past. I am not repeating them; I pass on the information.

VERY much a talking point recently has been the unfortunate SL-1 accident at Idaho. Various theories have been advanced for its cause. Among these is one that speculates on the possibility of the central control rod sticking; a manual effort being made to loosen it and the rod suddenly coming free and rising higher than intended. This happened when the core was significantly more reactive than it was supposed to be. However, it remains a theory and establishing the cause must wait till the final analysis by the Board of Investigation. What is more important is the implication of the accident on overall reactor safety and development in general. I recall the 1957 hazard report on the SL-1 (then known as the ALPR) prepared by the Argonne National Laboratory when it was stated that the ALPR was an inherently safe plant and able to operate with only the extremely remote probability of a dangerous nuclear incident. More information will be needed before any conclusions can be drawn but I have no doubt that the AEC will look closely at such matters as operating and maintenance procedures and safety reviews. A start has been made as the AEC is evaluating its own and licensed reactors.

The speed with which the AEC has made such an amount of information about the incident available is to their credit. Not only did they publish an interim report but daily issues were made of developments as well as a technical briefing of industry and press representatives shortly before the interim report appeared.. These actions contrast with the official air of chaste aloofness displayed after the Windscale mishap.

On Record

'Two examples of new problems which have arisen during the year and which may have a delaying effect on some phases of our programme are the development of stress cracks in the Dresden control drive index tubes and the fouling of the fuel element surfaces in the organic-moderated reactor experiment. In the former case, the problem could be widespread since most of the water reactors now in existence employ the material which is causing problems in the Dresden reactor.'

Robert E. Wilson, AEC Commissioner, before the Joint Committee on Atomic Energy.

'. . . there are strong indications that colleges and universities must substantially increase their capability of producing qualified nuclear engineers, scientists and medical personnel, as well, if the expected accelerated growth in atomic energy during the period between now and 1970 *is not to be thwarted by the lack of trained manpower.'*

A. R. Luedecke, General Manager, AEC, at the dedication of the University of Maryland's nuclear reactor.

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Neutrons:
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Current Capacity:
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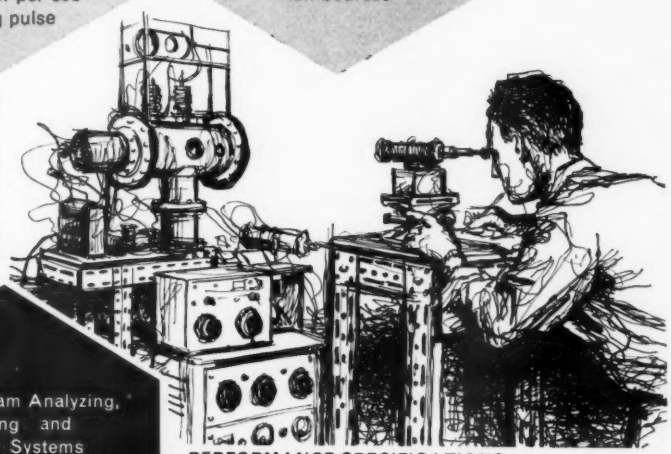

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BUSINESS NEWS

SOLARTRON'S SOVIET ORDER The **Solartron Electronic Group** are to supply the USSR with electronic apparatus and spares valued at more than £84,000. A contract covering this was recently signed with representatives of **V/O Mashpriborintorg,** Moscow. The order includes the supply of two automatic X-ray fluorescent spectrometers, three digital data recorders and a large number of digital voltmeters and electronic instruments. Total trade between the Soviet Union and the Solartron Electronic Group could well exceed £250,000, the company says.

GEC-ICT SUBSIDIARY A new subsidiary, **ICT (Engineering) Ltd** has been formed by **International Computers and Tabulators Ltd** (ICT) whose nominal capital will be held 90% by ICT and 10% by the **General Electric Company Ltd.** The new firm will assume responsibilities now undertaken by ICT's research and design division and by the GEC computer development department at Coventry. GEC will continue to supply ICT with a substantial proportion of its electronic equipment. In 1956, ICT and the GEC formed a jointly-owned subsidiary, **Computer Developments Ltd (CDL).** With the formation of the new company, ICT will take over the majority interest in CDL.

SIZEWELL PUMP CONTRACT A contract worth about £100,000 for 16 low pressure and 16 high pressure glandless motor pump units for water circulation in the Sizewell nuclear power station heat exchangers has been awarded to **Hayward Tyler & Co Ltd** by **Babcock & Wilcox.** Hayward's are one of the **Stone-Platt** group of companies.

EXPANSION FOR CONTROL FIRM **Integra Leeds and Northrup Ltd** has changed its name to **Leeds and Northrup Ltd** following the acquisition of all the outstanding shares not previously owned in it by the **Leeds and Northrup Company of Philadelphia.** The parent firm is to supply additional capital to enable the company to build new works and embark on a development programme and expansion of its present plant. Leeds and Northrup produce electrical measuring and control instruments and heat treatment furnaces.

PACE SYSTEM FOR EURATOM A large PACE analogue computing system nas been bought by **Euratom** for its Ispra research centre in Italy. The cost was about $375,000 and delivery of the installation is expected to be completed in the first half of this year. The system, says the European division of **Electronic Associates,** will consist of two expanded 231R machines with associated non-linear equipment. Electronic Associates Ltd also have a computing centre at Burgess Hill, Sussex, which recently received its first 'paid' job from **Rolls Royce Associates,** Littleover, Derby. EAL recently sold a 231R machine to **Vickers-Armstrong,** Weybridge, for £47,000.

ELECTRONIC FIRMS' AGREEMENT **Lancashire Dynamo Electronic Products Ltd,** Staffordshire, has a licence agreement with **Emerson Electric Manufacturing Co,** St. Louis, Missouri, under which the US company will have the right to manufacture on a royalty basis the range of industrial electronic equipment made and designed by the British company over the past 15 years.

• **Elliott Brothers (London) Ltd** have formed a new subsidiary, **Rotron Controls Ltd,** jointly with **The Rotron Controls Corp** of Woodstock, New York. Elliott's have a two-thirds controlling interest.

• **H.M.K. Sales Ltd,** formerly **Millspaugh (Canada) Ltd,** is to control and promote the marketing in Canada of the products of the **Hadfields** group of companies.

• **Blackburn Electronics Ltd** has received orders for data logging equipment for a new power station being built near Mol, Belgium.

• Work has started on a £55,000 laboratory and workshop building for **Nuclear Enterprises (GB) Ltd.** This is the second sizeable expansion within two years.

• The Solenoid Valve Division of **Ether Ltd** has been awarded a contract by the main contractor for the R3/ADAM heavy water reactor to be built in Sweden.

• **D. Napier & Son Ltd** and **Telegraph Construction Maintenance Co. Ltd** exhibited at the Leipzig Spring Fair in March.

OVERSEAS

US FOREIGN PATENTS A revised foreign patent policy has been adopted by the USAEC. This concerns inventions derived from work done under AEC contracts in privately-owned and operated facilities. Under the new policy, AEC contractors filing US and foreign patent applications will retain: (a) non-exclusive paid-up licences for all purposes in any such US patent application and (b) the rights and title in any such foreign application or foreign patents secured by the contractor. The AEC has also adopted a new policy under which it will grant licenses for royalties on AEC-owned foreign patents to foreign corporations and nationals in those countries which require royalties from the US government or US citizens. Where a foreign government does not require these royalties, the AEC will continue to grant free licenses.

FOOD IRRADIATION CENTRE Negotiations with **Associated Nucleonics Inc.** to serve as the architect engineer in the design of a food irradiation centre at Natick, Massachusetts, are being undertaken by the AEC. The facility will employ two radiation sources—a one million curie Cobalt 60 source and a 24 MeV linear accelerator. The centre is planned for completion in the summer of next year and will be made available to Government agencies for food preservation studies.

FUEL ELEMENT COLOUR CODES A colour coding system for fuel elements for research and test reactors has been introduced by **Sylvania-Corning Nuclear Corporation.** It was developed for pool-type reactors and is designed to make fuel element identification easier and safer for reactor operators. By using a different system colour for each type of fuel element, these can be easily identified even though covered by 15-20 ft of water.

GERMAN SHIPPING FIRM The Hamburg Gesellschaft füer Kernenergieverwertung in Schiffbau und Schiffarht (GKSS) has stated that the German Federal Government together with four coastal Land governments are to take over most of its shares. They are to have 51% of the share capital—this step was necessary because these five bodies were carrying the main costs of research and development work being conducted by GKSS.

• **A/S Noratom** of Oslo are to be the consultants in the building of a waste storage centre for the **Eurochemic** plant at Mol, Belgium.

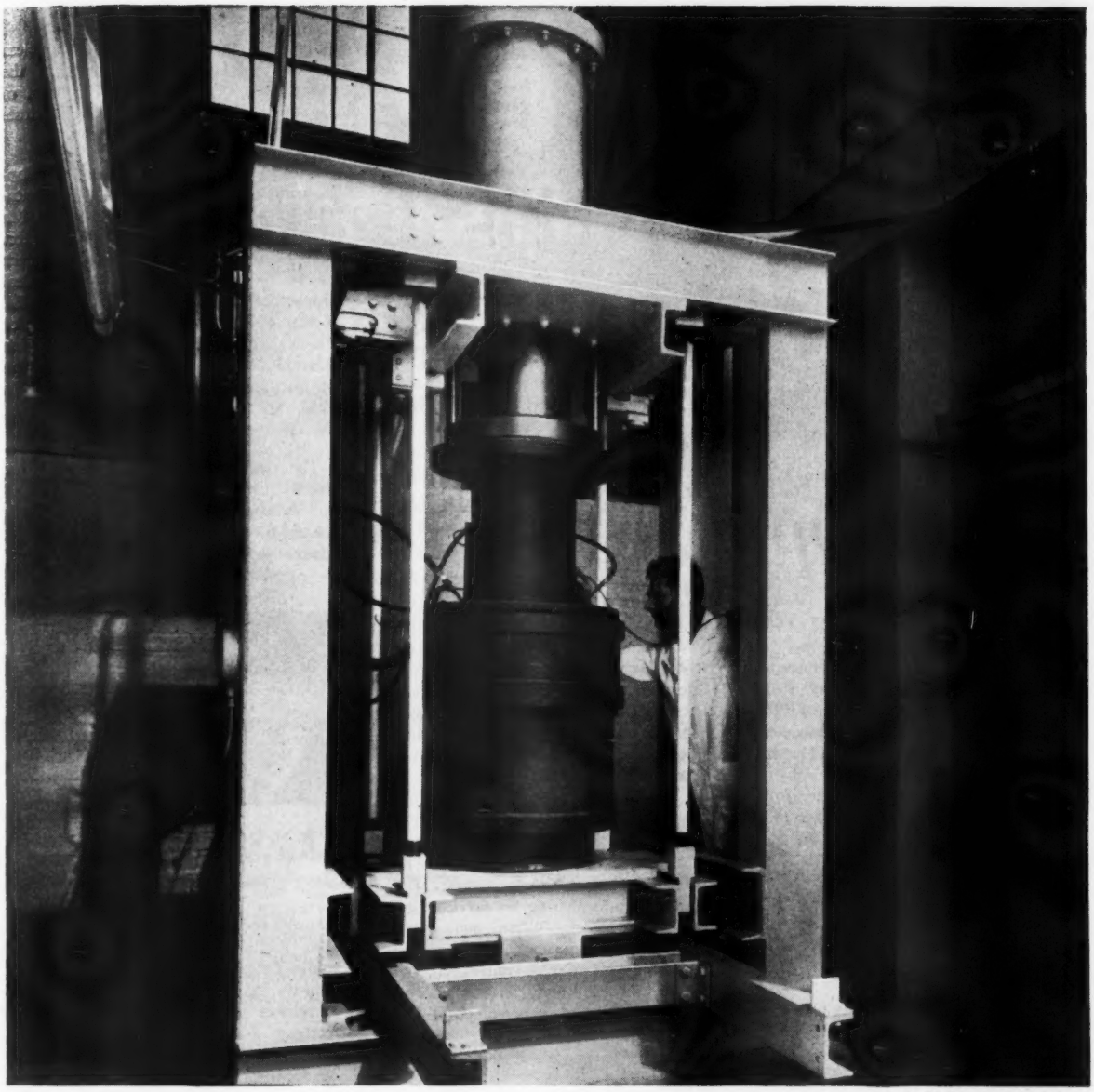
• A hot laboratory, manufactured and supplied by **Atomic Energy of Canada Ltd,** has been completed for the Japanese **Telephone & Telegram Corporation.**

• The first annual meeting of the **Canadian Nuclear Association** will be held in Toronto on May 16-17.

• The **IAEA** has awarded a contract to the **Institute of Nuclear Research,** Czechoslovak **Academy of Sciences,** to ascertain the physicio-chemical requirements for the disposal of low-activity liquid radioactive wastes in soil.

• **Euratom** is to establish an information bureau on the applications of radioisotopes.

• The **Tokyo Shibura Electric Co** has made a 15 MeV betatron for the Medical Faculty, Osaka City University. This is the first time a 15 MeV betatron has been made in Japan for medical purposes.



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At work during the successful 100 kW Jason reactor run are members of the reactor team including Bruce Emmerson (rear), the reactor supervisor, and Colin Hughes (second left) the senior physicist. The operation at 100kW was at ten times the rating for which this Hawker Siddeley reactor was originally designed (see *Worldview*, March p 53)

People

by John Radford

AT THE age of 37, **John S. Hollings** has been appointed to the Board of Rolls-Royce and Associates Ltd. He joined Rolls-Royce in 1948 as a graduate apprentice and in 1955, after attending a course at Harwell, led the design section working on the nuclear submarine project. With the formation of Rolls-Royce and Associates in 1959, Mr Hollings was appointed chief designer.

Another under-40 top level appointment is that of **Mr Harry Williamson,** managing director of Fischer & Porter Ltd, Workington. He is also to be managing director of Fischer & Porter NV, in Holland. The

JOHN S. HOLLINGS — HARRY WILLIAMSON.
Both under forty

appointment signifies the increasingly close co-operation existing between the British and continental affiliates of the American flowmeter and process control instrument manufacturing concern, Fischer & Porter. Mr Williamson, by his own admission, is essentially an engineer but this in no way limits his executive ability. He is also a director of Chlorination Equipment Ltd.

Managing director of Holland & Hannen and Cubitts (Great Britain) Ltd, is **Mr J. M. Harris** who has been in charge of Cubitts' Structural Engineering Department since 1947. He was appointed to the board in 1958 and is also a director of Holland & Hannen and Cubitts (Scotland) Ltd and of Concrete Development Co. Ltd.

After retiring from the Royal Air Force with 32 years service, **Air Vice-Marshal W. E. Oulton** has joined the board of EMI Electronics Ltd as director responsible for Ministry work. During his service career, Air Vice-Marshal Oulton acquired an international reputation as an expert on navigation, air traffic control, anti-submarine warfare and nuclear weapons testing. He played a prominent part in setting up the London Air Traffic Control Zone in 1946.

Charles H. Weaver, vice-president in charge of atomic power for Westinghouse Electric Corporation, has been elected president of the Atomic Industrial Forum, Inc. He has served as a director of the Forum since 1955 and has been chairman of its budget and finance committee for the past two years. Mr Weaver joined Westinghouse in 1936 and in 1948 became the first manager of the company's atomic power division.

Appointed as first general manager of the newly formed Canadian Nuclear Association is **Roy F. Gross,** a professional engineer whose background includes top level administrative and liaison work in Canada and abroad. He will devote his time to encouraging co-operation between the various industries, utilities, educational institutions, government departments and agencies who have a common interest in the peaceful uses of nuclear energy. Mr Gross is a member of the Association of Professional Engineers of Ontario and of the Engineering Institute of Canada.

Responsible for the design and development of all chemical analysis instrumentation at Southern Instruments Ltd is **Mr H. M. Davis,** chief engineer and director. In 1937, Mr Davis was with the Department of W. D. Chemist (later MoS Chemical Inspectorate) and was seconded to the AEA Research Group in 1955. He was head of Physical Methods Section at Woolwich Arsenal and was engaged on investigation of instrumental methods of analysis. In 1958, Mr Davis was a UK delegate at the Geneva conference.

The new European sales manager for Brooks Instrument Co. S.A. of Switzerland and Brooks Instrument Nederland NV is **Austin F. Platt.** He has had ten years experience in the instrument and control

H. M. DAVIS
Chief engineer

AUSTIN F. PLATT
Sales manager

industry and has directed sales, supervised sales promotion and conducted market studies for prominent US companies in the industry. A graduate engineer, Mr Platt is a member of the Instrument Society of America.

Mr R. Cox and **Mr B. Yates** have been appointed directors of Low Moor Fine Steels Ltd.

Earl D. Needham is director of material for Atomics International, a division of North American Aviation.

Robert C. Dunlap, Jr, is a vice-president of Texas Instruments Inc. and will become operating head of the company's geosciences activities.

Mr J. W. Haig-Ferguson was recently made managing director of R & J Beck Ltd, manufacturers of optical instruments for surveying, industry, education and research.

Professor Vasily Emelyanov, chairman of the USSR Atomic Energy Committee, has been awarded the Order of Lenin for his services in developing Soviet nuclear science and technology.

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✱ **Lower inventories.** Benefits large users of instruments by utilizing actuating elements which are common with FULSCOPE and other Taylor indicating, recording and controlling instruments.

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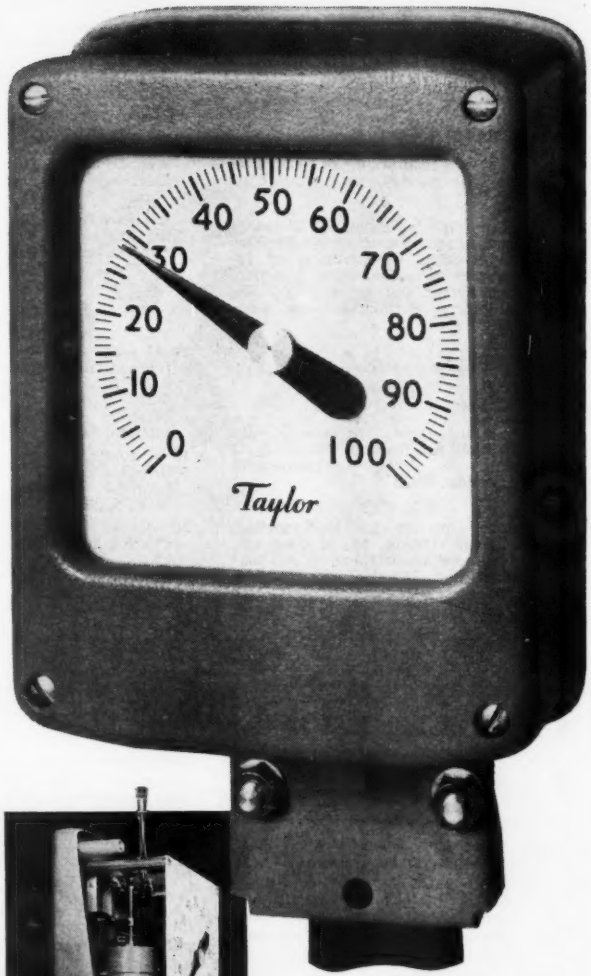

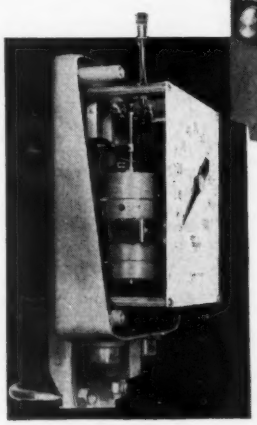

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Diary

5 APRIL
Radioisotopes in industry, Grand Hotel, Bournemouth, 7.30 pm. Southern branch meeting, Institution of Plant Engineers

5–7 APRIL
Electrical contacts symposium, London. Details, Secretary, Institute of Physics, 47 Belgrave Square, London, SW1

10–15 APRIL
First International Congress on **Metallic Corrosion,** London. Details, Lt-Col F. J. Griffin, Society of Chemical Industry, 14 Belgrave Square, London, SW1

12 APRIL
New metals and alloys as materials of construction etc, Birmingham University, 9.30–5.30. Details, Institution of Chemical Engineers, 16 Belgrave Square, London, SW1

12–14 APRIL
Developments in the chemistry of boron compounds and some aspects of the chemistry of natural products, Department of Inorganic and Physical Chemistry, Liverpool University. Symposium organized by The Chemical Society, Burlington House, London, W1

14 APRIL
Scientific films, Royal Institute of Chemistry, Windscale Club, Seascale, 8 pm

17–18 APRIL
Spring meeting, Powder Metallurgy joint group, Iron & Steel Institute and Institute of Metals, at Royal Commonwealth Society, London, WC2

17–19 APRIL
International meeting on **fluid sealing,** Ashford, Kent. Details, Mr H. Stephens, British Hydromechanics Research Association, South Road, Temple Fields, Harlow, Essex

18 APRIL
The application of irradiation in industry, M. C. Crowley-Milling. Meeting of North Midland Utilization Group, Institute of Electrical Engineers, at Leeds Conservative Club, 6.30

18–19 APRIL
Science and Industry—the problem of communications, Swansea. Conference organized by the Department of Scientific and Industrial Research. Details, DSIR Liaison Officer for Wales, Block II, Government Buildings, Gabalfa, Cardiff

20 APRIL—4 MAY
Engineering, Marine Welding and Nuclear Energy Exhibition, Olympia, London.

24 APRIL
Fluid fuel reactors, A. M. Weinberg, Geological Society, Burlington House, London, W1, 5.30 pm. Details, Institution of Chemical Engineers, 16 Belgrave Square, London, SW1

25 APRIL
Annual meeting, Institution of Marine Engineers
Annual meeting, Institution of Chemical Engineers

28 APRIL
Ion exchange, T. R. E. Kressman. Society for Analytical Chemistry meeting, Central Hotel, Carlisle, 7.15 pm

Future months

10–12 MAY
International conference on **materials handling,** Prince of Wales Hotel, Southport. Details, H. M. C. Harwood, Institute of Materials Handling, 32 Watling Street, London, EC4

12–15 JUNE
British **Electrical Power Convention,** Eastbourne. Enquiries, Secretariat, BEPC, Wimsley Street, London, W1

20–26 JUNE
Third congress, European Federation of Chemical Engineering, Olympia. Enquiries, Institution of Chemical Engineers, 16 Belgrave Square, London, SW1

7–29 JULY
Soviet trade fair and exhibition, Earls Court, London

4–9 SEPTEMBER
International conference on **the discovery of the nucleus,** Manchester. Details, The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, SW7

OVERSEAS

4 APRIL
Uranium carbides as reactor fuel materials, USAEC symposium, Germantown, Maryland. Details, Industrial Co-operation Branch, Division of Reactor Development, USAEC, Washington 25, USA

5–7 APRIL
Materials for electron tubes and semiconductor devices, symposium, Philadelphia. Organized by the American Society for Testing Materials, 1916 Race Street, Philadelphia, USA

10–14 APRIL
IAEA symposium on **detection and use of tritium** in the physical and biological sciences. Location undecided

10 APRIL—21 MAY
Seventh Commonwealth mining and metallurgical congress. Details, Congress Manager, 5 Hollard Street, PO Box 809, Johannesburg, South Africa

11–12 APRIL
Radiation effects in inorganic solids, Faraday Society, at Centre d'Etudes Nucléaires de Saclay. *Admission by invitation*

11–18 APRIL
Fourteenth assembly, International Institute of Welding, New York. Details, Secretary General, 34 Princes Gate, London, SW7

17 APRIL
Conference to consider draft convention of **third party liability and indemnification resulting from operation of nuclear powered ships,** Antwerp. Arranged by Comité Maritime Internationale

Industrial Literature

Electronic engineering. AEI's various house journals have now disappeared and their place has been taken by the new ' AEI Engineering ' covering the activities of the Company as a whole. The first two issues published are very well produced and illustrated. The January number contains an article on the precise measurement of small objects based on a microscope application developed at Aldermaston, and another on the basic requirements for high-power transistor operation. Resulting from work at the Harlow research laboratory, the February issue includes a discussion on the use of cadmium sulphide crystals for gamma-ray detection.
★ 251

Radiation measurement. ' Electricity ' in Industry ', the technical journal of Metal Industries, contains an article by Avo's Managing Director reviewing recent developments in portable radiation measuring instruments.
★ 252

Uranium production. Canada's estimated reserves of uranium, or uranium oxide equivalent, is 370,200 tons ; 23 mines and 19 treatment plants are in operation. Full details about these activities are given in the official information bulletin MR44—' Survey of the Uranium Industry in Canada, 1959 '.
★ 253

Radioactive sources. Eighteen new organic compounds labelled with carbon-14, ranging from insecticides to steroids, new sulphur-35 compounds and others labelled with phosphorus-32 and tritium, are included in supplements to the UKAEA's catalogues of ' Radioactive Chemicals ' and ' Radioactive Sources '.
★ 254

Flow measurement. The series of articles published between 1952 and October 1959 under the title ' The History of Flow Measurement by Differential Pressure ' have now been reprinted by Kent in one volume.
★ 255

Commercial isotopes. Compiled from current catalogues and other sources, the new edition of ' The Isotope Index ' for 1960–1961, published by Scientific Equipment (price $5·50), contains more than 5500 items from more than 50 US, Canadian, British, French and German suppliers. In addition to half-life and principal radiation energies, data includes the chemical name or formula, specific activity, supplier, catalogue no. and latest prices.
★ 256

Aluminium extrusions. Extruded sections produced by Impalco are specified in two recent publications. Volume 1 gives a complete range of flat bars, rounds, squares, hexagons, angles and other types useful in general and constructional work; volume 2 arranges by shapes for which dies are held.
★ 257

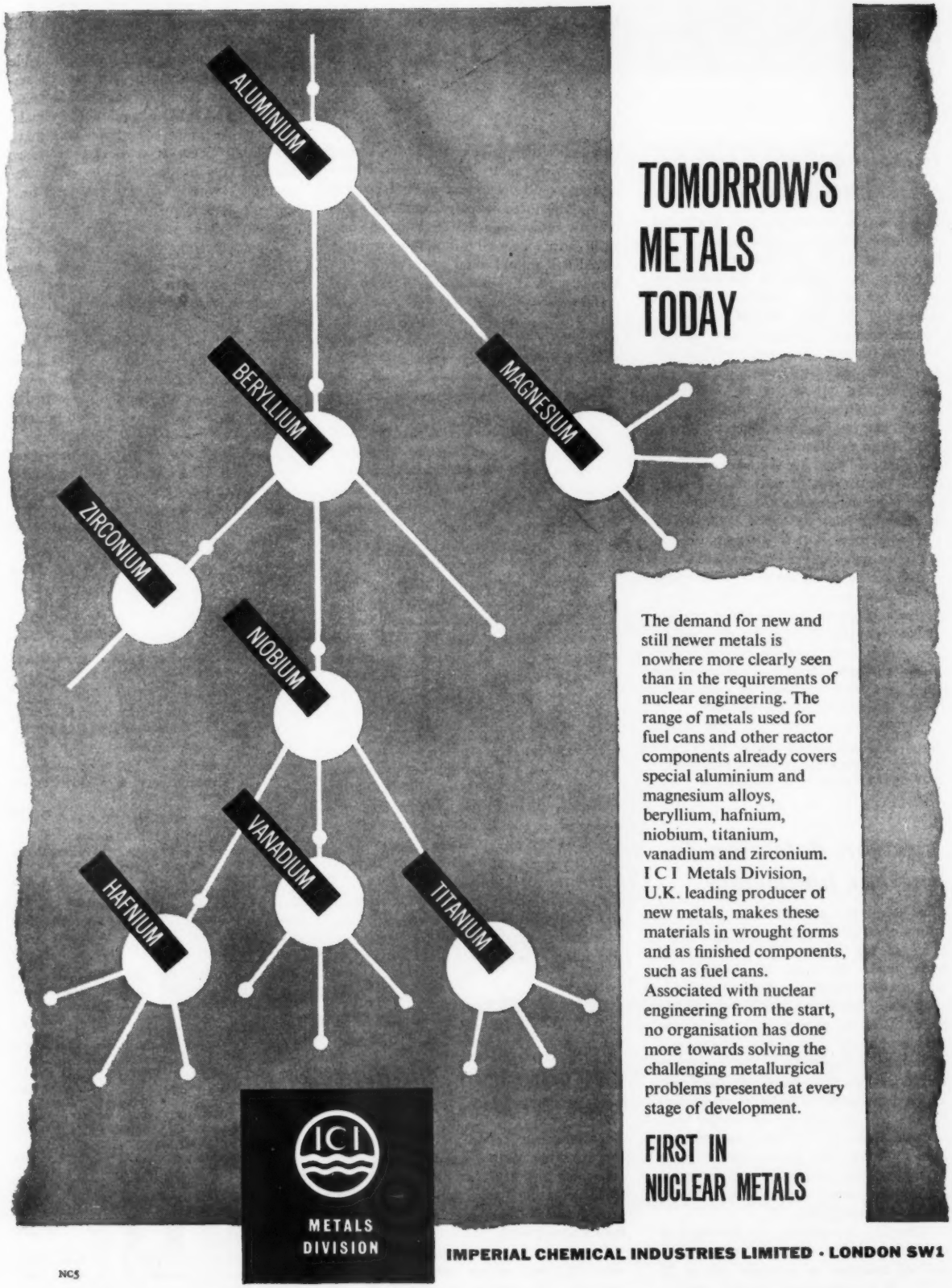
Decade voltmeter. The more precise industrial measurement of absolute r.m.s. voltage is now possible with the D-930-A Muirhead-Wigan r.m.s. decade voltmeter. An article in the current issue of ' Technique ' covers circuitry and applications.
★ 258

Soil density measurements. A new brochure from Nuclear-Chicago describes the use of nuclear gauges for rapid field determination of moisture and density in soils, aggregates, concrete, asphalt, etc.
★ 259

Electronic valves. STC continue their series ' Choosing the right component ', in ' Component News ', by considering the various characteristics and design features of radiation-cooled and cold cathode valves.
★ 260

Data processing. A detailed description of the Pegasus 2 computer system, now available from Ferranti, covers the common language and direct processing systems, punched card working, high speed printing, magnetic tape and pseudo off-line working and representation of data within the system.
★ 261

★ *For further information on any item, circle the appropriate number on the reply card facing page 122*



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The demand for new and still newer metals is nowhere more clearly seen than in the requirements of nuclear engineering. The range of metals used for fuel cans and other reactor components already covers special aluminium and magnesium alloys, beryllium, hafnium, niobium, titanium, vanadium and zirconium. I C I Metals Division, U.K. leading producer of new metals, makes these materials in wrought forms and as finished components, such as fuel cans. Associated with nuclear engineering from the start, no organisation has done more towards solving the challenging metallurgical problems presented at every stage of development.

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Book Reviews

Russia quiet on Waste Disposal

This is an eminently readable book and contains a wealth of information. The fixation of fission products on to clays and glass, for instance, is the subject of many informative papers. This is apparently the only method considered for the treatment of highly active liquors prior to storage. Its importance is evident from the great amount of work being carried out as yet, unfortunately, mainly on laboratory or pilot plant scale.

Excellent papers on chemical treatment methods illustrate the similarity in the methods used in the various countries. The subject of evaporation, when very high decontamination factors are necessary, is also described in detail.

It is perhaps rather disappointing to find only one paper from the USSR out of the whole proceedings. As a result little information regarding their disposal methods is given, and virtually nothing further is added during the discussions. The subject of disposal in the sea is widely discussed and it is obvious that there is a wide cleavage of opinion as to the desirability of this method.

J. H. Clarke

Disposal of radioactive wastes, Vol 1 Conference Proceedings, Monaco, November, 1959 IAEA, Vienna, 1960 612 pp, Price 36s.

Neutron detection for nuclear physicists

The literature of neutron detection is voluminous and, in spite of the importance of the subject, little attempt has been made to date to produce an authoritative work of reference covering even the most important aspects. The difficulty of an exhaustive study of the field is to avoid producing a catalogue of references if the book is not to run to encyclopaedic dimensions. In his book, aimed principally at workers in nuclear physics not previously concerned with neutron detection, Dr Allen has attempted a middle course in providing a guide to the subject, illustrated with practical applications and supplemented by a generous bibliography.

Adequate descriptions are provided of most of the methods used for the detection of neutrons of energies up to 20 MeV. It is unfortunate, though perhaps inevitable, that in general the book only covers work up to 1957, although later references do occur and more especially in the first three chapters, there are some curious omissions of well known work. It is surprising that an author working in AERE should omit mention of the Denis and Loosemore proton recoil counter while describing in some detail the Hurst counter. Again although reference is made to the RC1 ionization chamber developed by Abson and Wade, which by 1957 was widely used, the obsolete TQT chamber is described as the standard for reactor control measurements. Similarly, American and French gamma compensated ionization chambers are described without reference to the AERE development of the RC6.

The general reader is likely to find the first part of the book the least satisfactory, but the later chapters dealing with applications of fast neutron detection and measurement, applications and standards are well handled. Chapters 1 and 2 suffer from confusion perhaps due to overcompression. In chapter 2 no clear distinction is drawn between radiative capture and activation and the latter process is referred to in one place as ' radioactive capture '. Both radiative capture and activation are discussed under the former as heading. Activation techniques which are far more important for neutron detection than radiative capture, are surveyed in this section but are not listed under the usual title in the index. The term ' radioactive detector ' for the foils used in activation techniques is also felt to be rather confusing.

In general, however, the book is readable and most useful as a source of information, collecting together much that was hitherto difficult of reference.

A. L. Gray

Neutron Detection by W. D. Allen, Newnes, London, 1960 260 pp, Price 45s.

Introduction to heat transfer design

This is a very good introductory text for both mechanical engineering undergraduates and also for practising mechanical engineers who find the need for heat transfer design as an adjunct to their normal work.

It does, in fact, concentrate very considerably on design and calculation methods and goes to the extent of suggesting how computer analysis should be carried out. It also deals extensively with electrical and other analogies which will undoubtedly assist in design work.

The presentation is readily readable and great care is taken with the explanation of the various heat transfer phenomena, and this will undoubtedly make it of great value to those who have occasional need of a design reference book. This is particularly true, for example, with the chapter on heat exchanger design work.

The chapter on ' Some Important Thermal Systems ' and ' Heat Transfer Testing ' are somewhat superficial, however, and add little value to the text, nor is their presentation particularly helpful. It would have been more useful to have given a much fuller treatment of heat transfer to thermocouples since these are fundamental to the test work described; many engineers are unfamiliar with the importance of careful design of thermocouples for use in their experiments.

The book can most certainly be recommended as a logical and readily understandable approach on a subject of growing importance.

M. J. Kemper

Heat Transfer Engineering by H. Schenk, Longmans, London, 1960, 314 pp. Price 28s.

New books

- *Practical nucleonics* by F. J. Pearson and R. R. Osborne. Spon, 1960 Price 37s 6d ★ 262
- *High Frequency applications of ferrites* by J. Roberts. EUP, London 1960 166 pp 16s ★ 263
- *Fundamentals of digital instrumentation* by D. S. Evans. Hilger & Watts, London 1960 39 pp Price 7s 6d ★ 264
- *Transactions of the 6th national symposium on vacuum technology, 1959* Pergamon, London 1960 335 pp Price £6 ★ 265
- *Resonance absorption in nuclear reactors* by L. Dresner. Pergamon, London 1960 131 pp Price 40s ★ 266
- *Nuclear propulsion* edited by M. W. Thring Butterworths, London 1960 300 pp Price 50s ★ 267
- *McGraw Hill Encyclopedia of science and technology*—15 volumes McGraw-Hill, London and New York 1960 Price £67 16s 6d ★ 268
- *Digital computers and nuclear reactor calculations* by W. C. Sangren. Wiley, London 1960 208 pp Price 68s ★ 269
- *Progress in nuclear physics, volume 8* edited by O. R. Frisch. Pergamon, London 1960 304 pp Price 90s ★ 270

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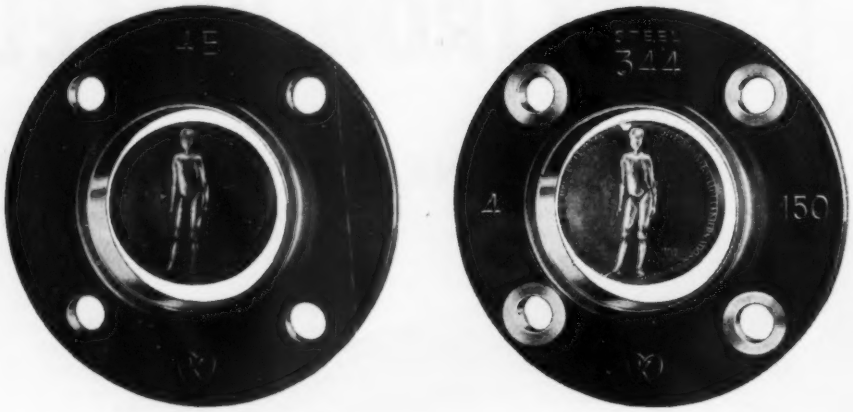

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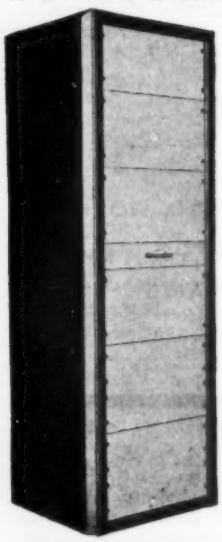

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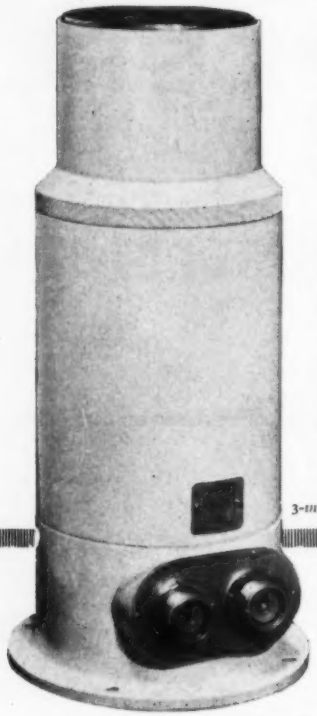

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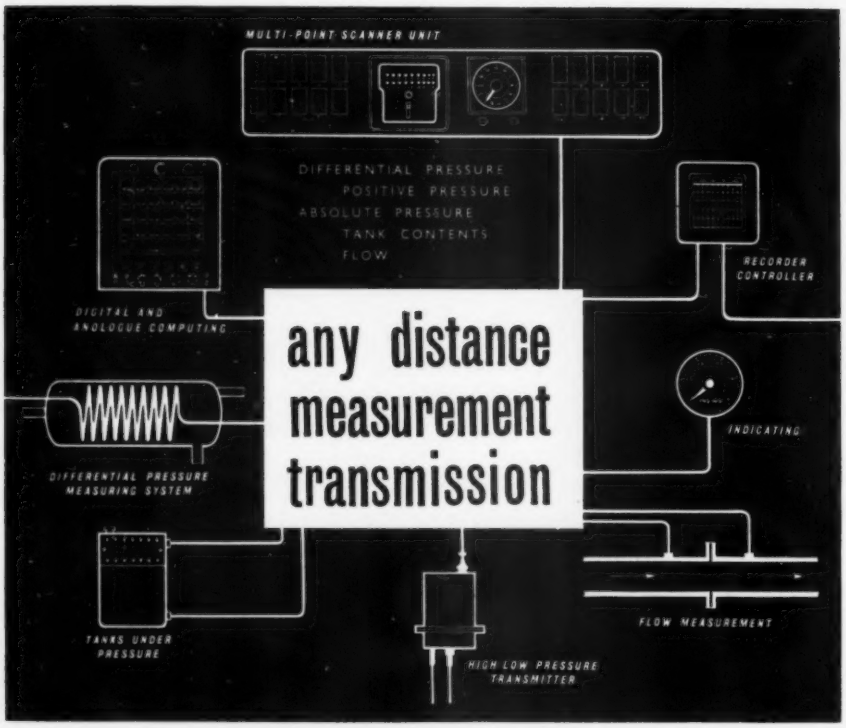

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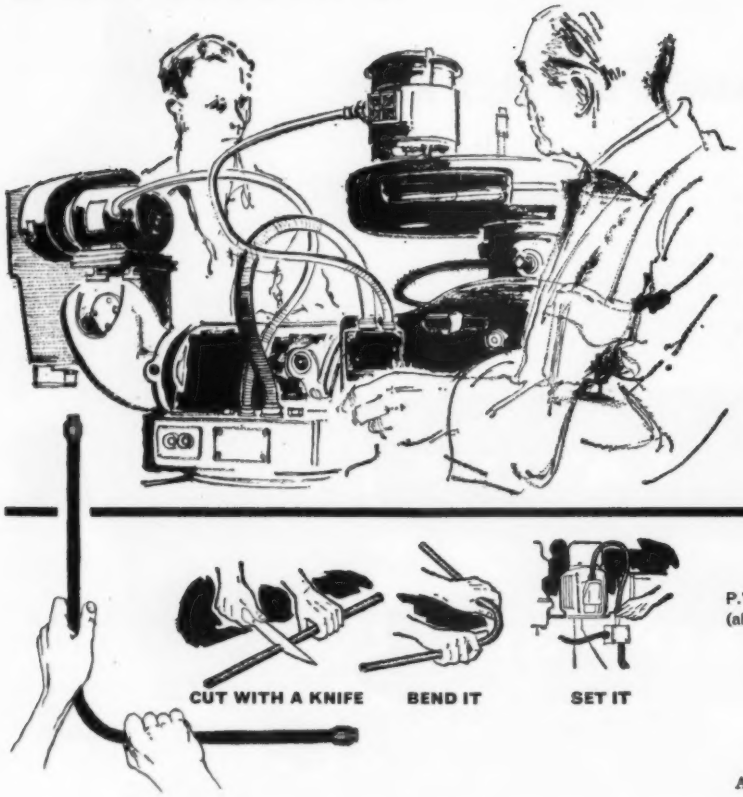

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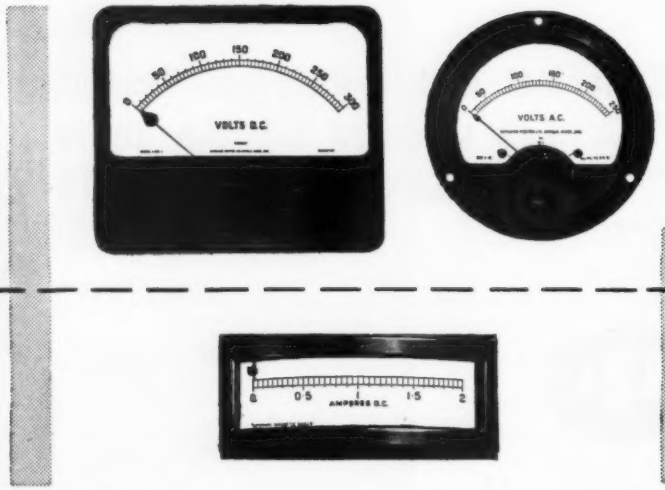

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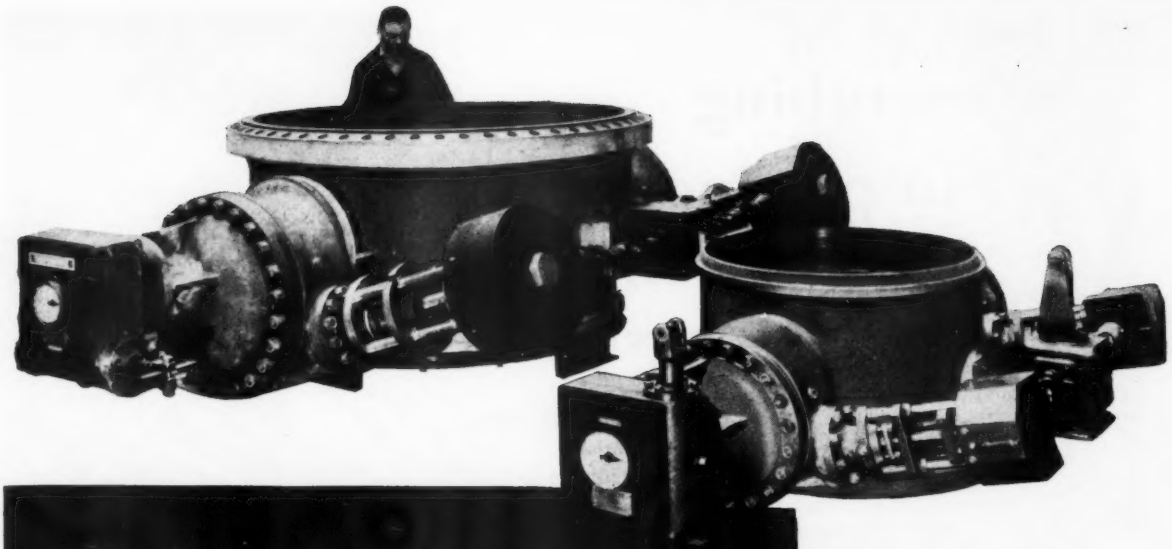

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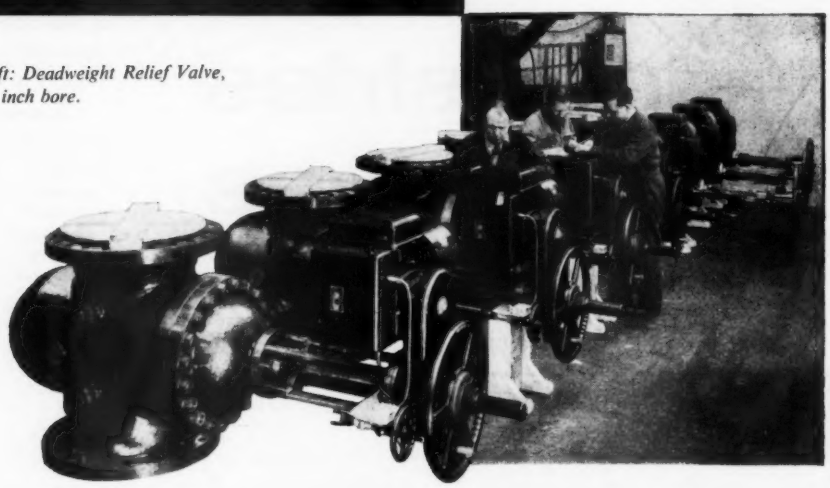
Above: "Tansphere" Valves for isolating CO_2 gas between reactor and steam generating plant. Supplied or on order for Bradwell, Hinkley Point, Latina and Trawsfynydd (Valves illustrated are 60 inch and 36 inch bore).

Below: Group of 24 inch electrically-controlled Hopkinson-Ferranti valves for a nuclear power station.

Left: Deadweight Relief Valve, 20 inch bore.



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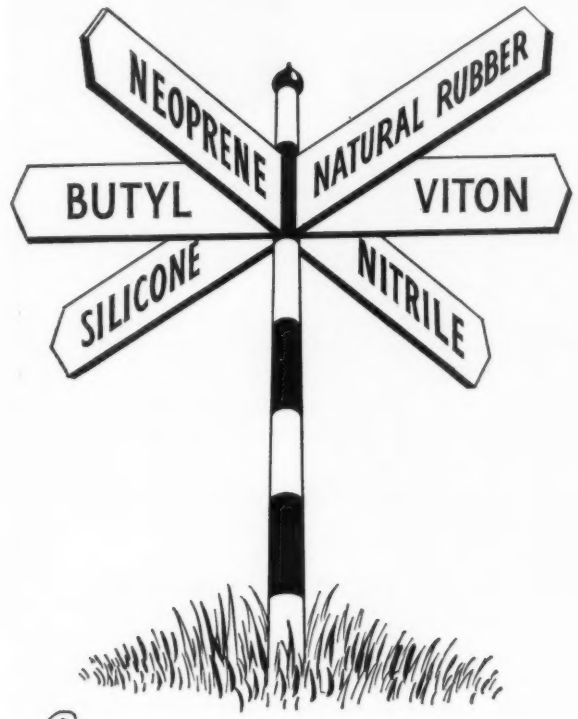

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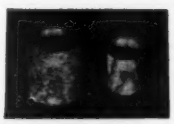

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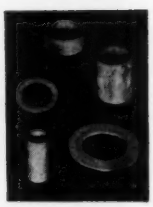
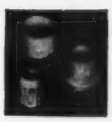


Bearing Power Loss



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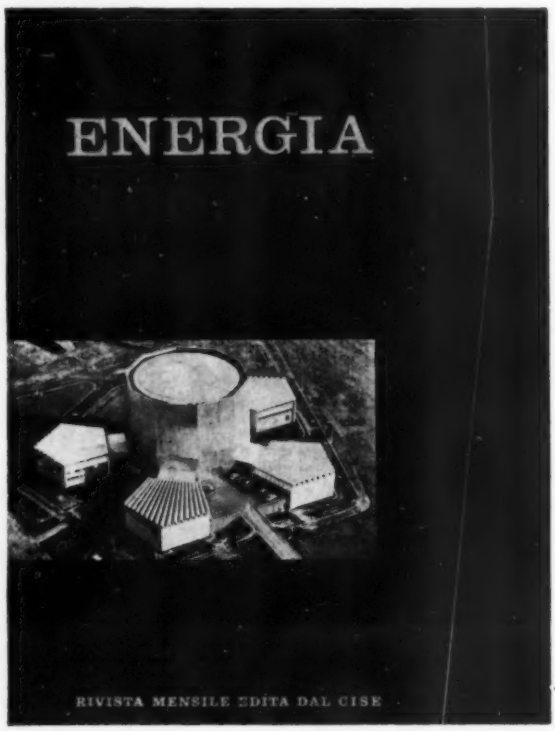

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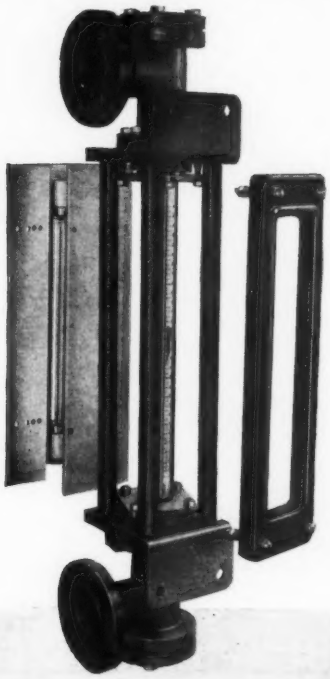

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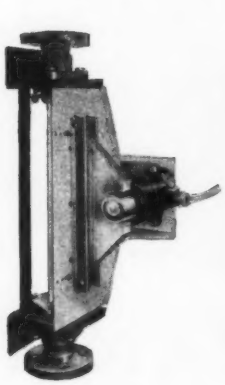
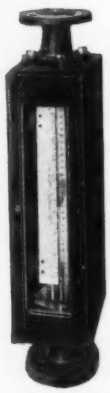
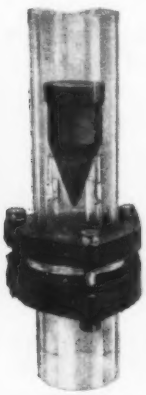


Illuminator



Type 917



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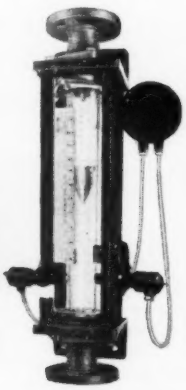

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Alarms

A photo-electric alarm to signal fluid flow above or below desired limits. Several alarms may be fitted to one instrument. The alarm will fit any size of type 907 or 914 instrument and may be installed without interrupting plant operation.

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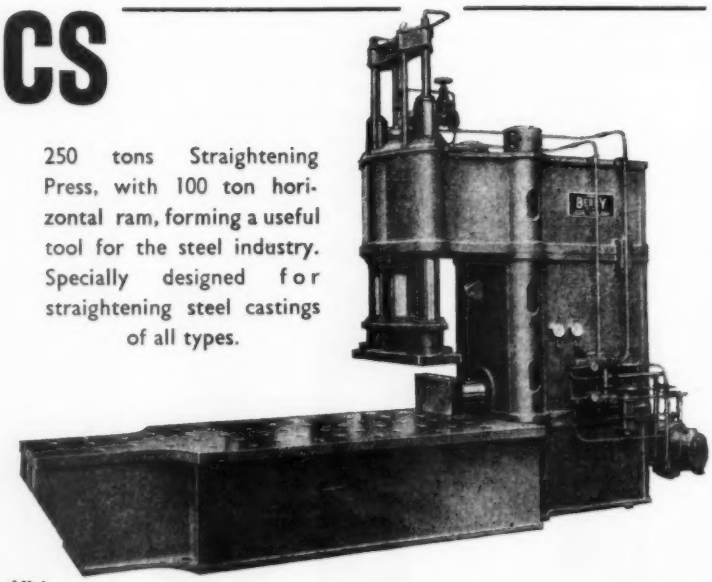

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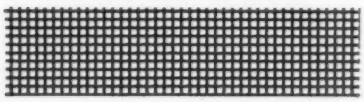

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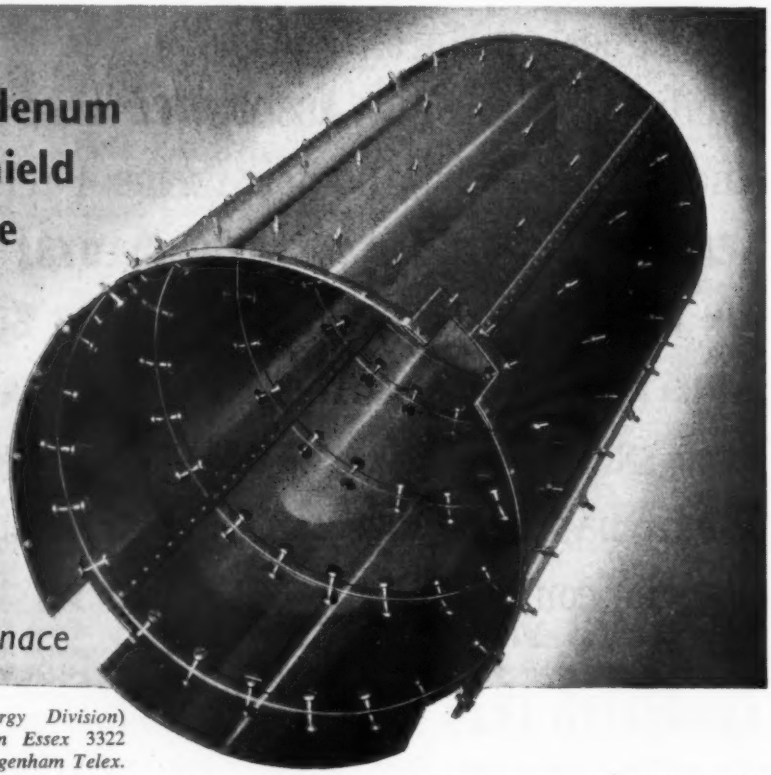

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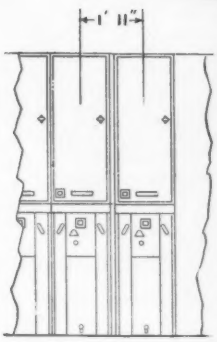

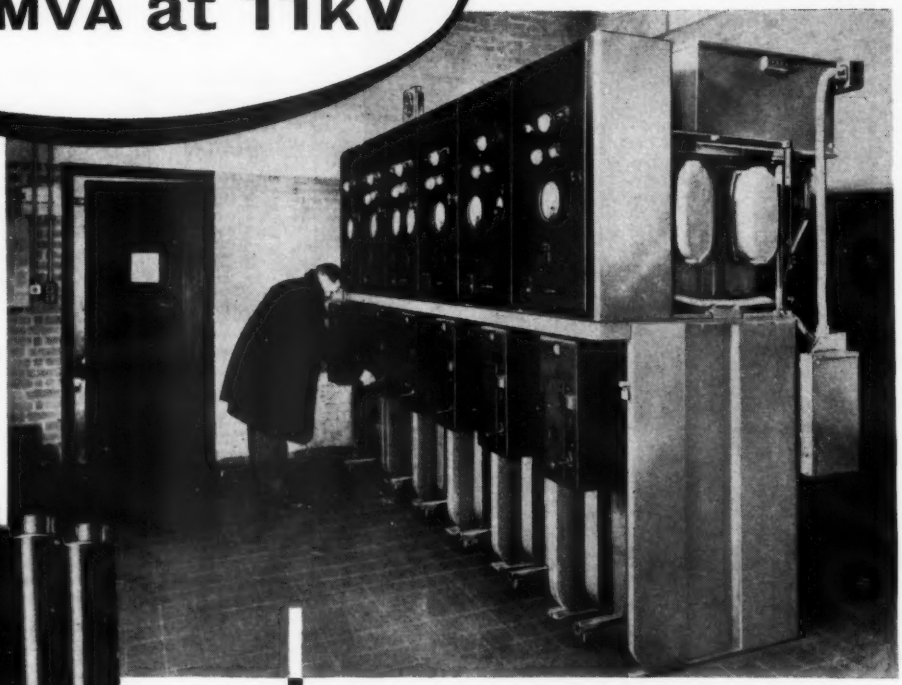

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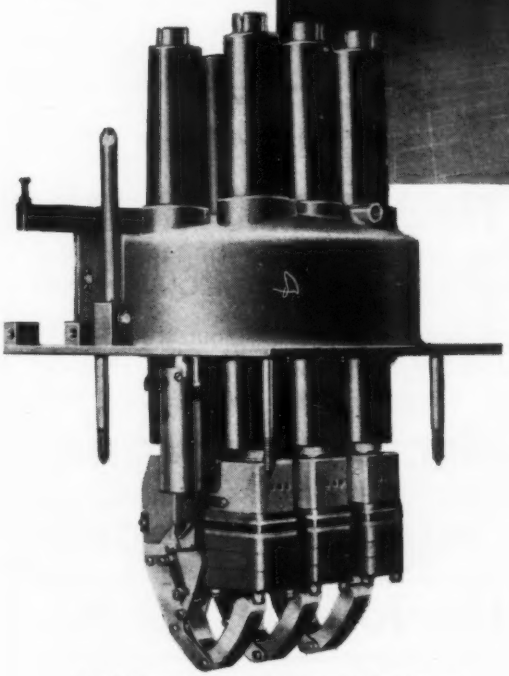

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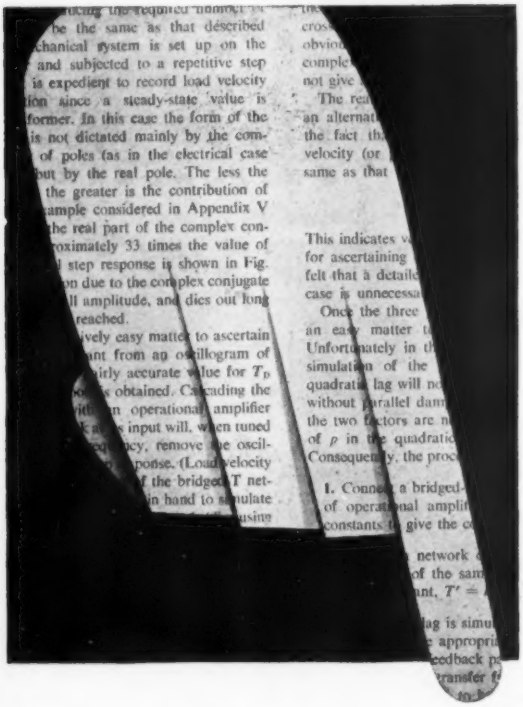

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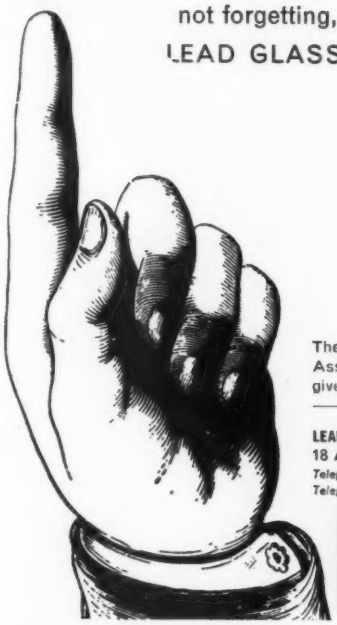

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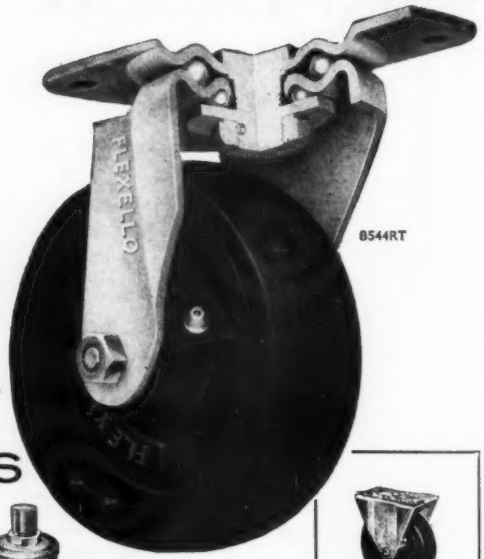

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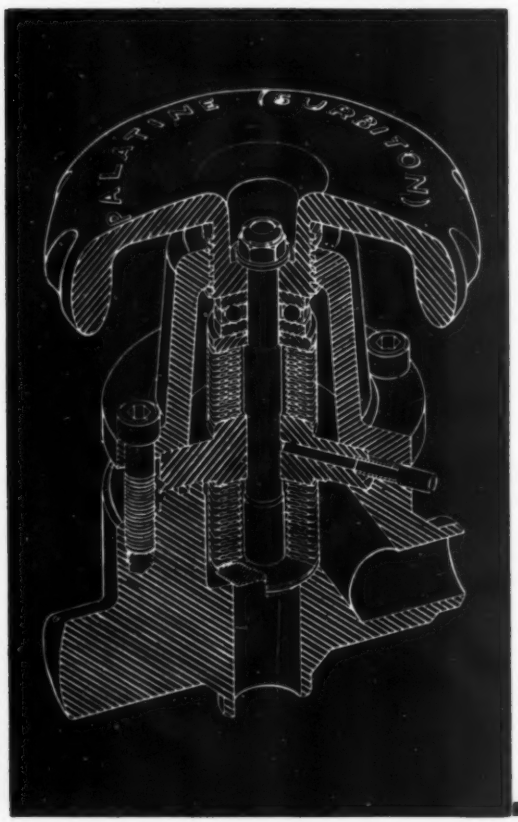

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Palatine design and supply a wide variety of Valves to U.K.A.E.A. at Capenhurst, Aldermaston, Harwell, etc. and to the Chemical and Petroleum Industries.

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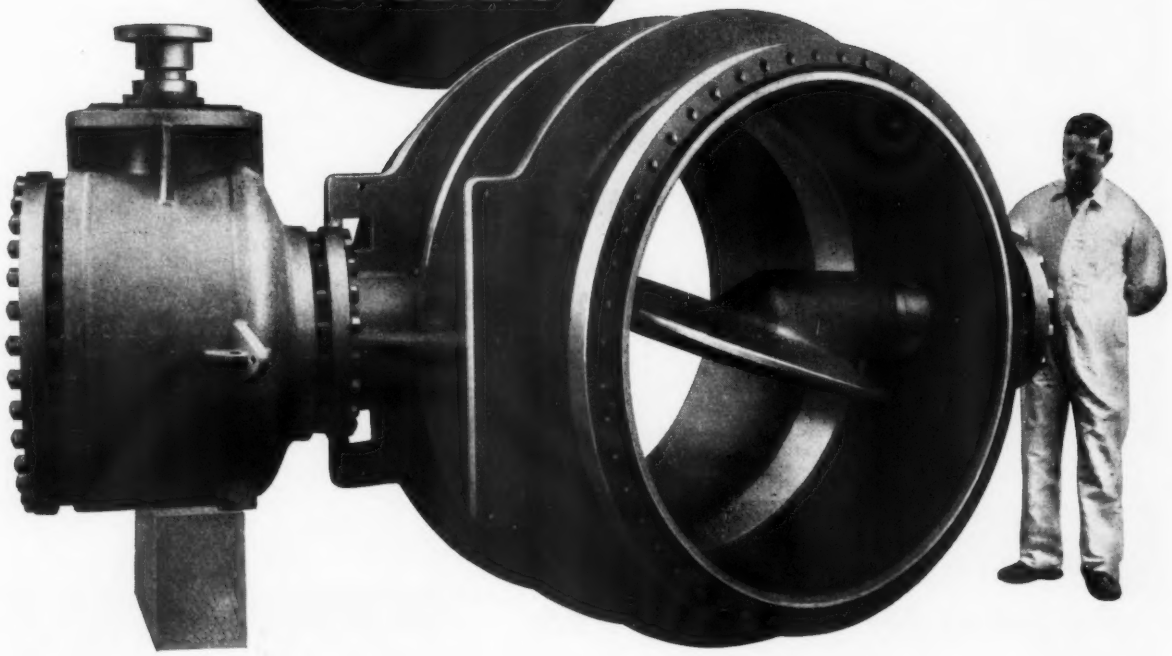

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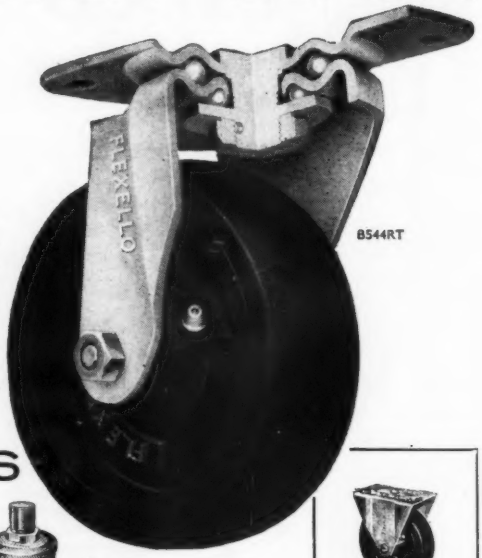
Substantial kingpin adjustable for bearing protection ▶
Minimum of maintenance ▶
Pre-greased hardened bearings ▶
Maximum ease of mobility ▶



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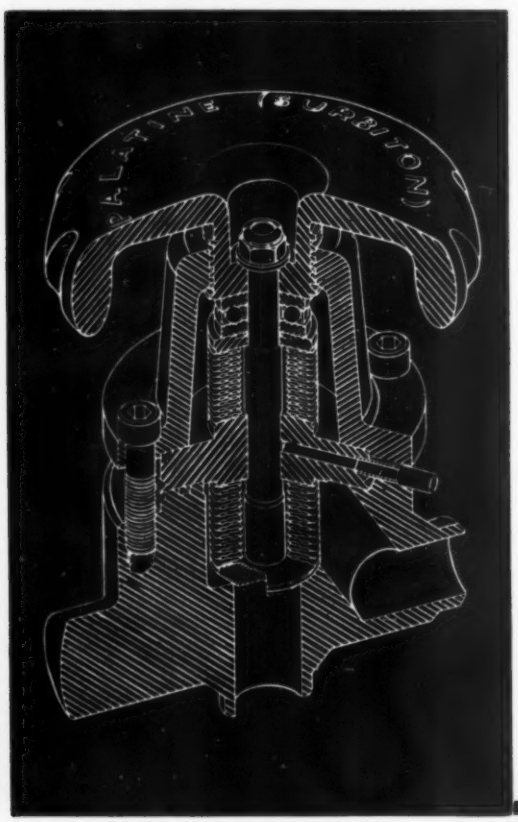

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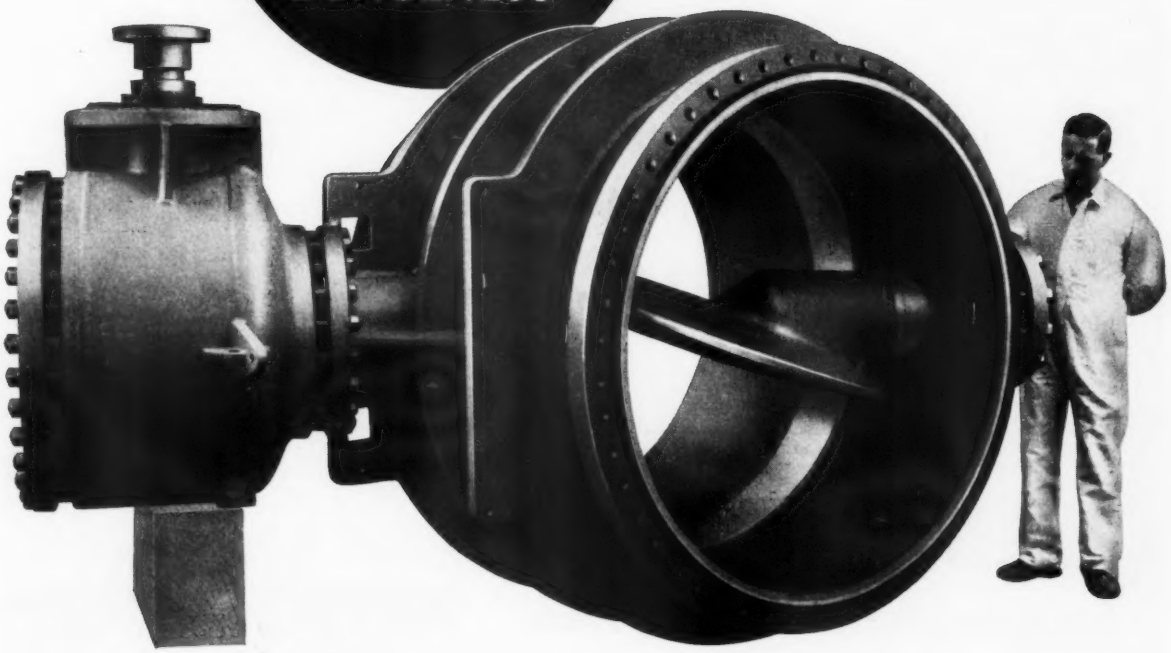

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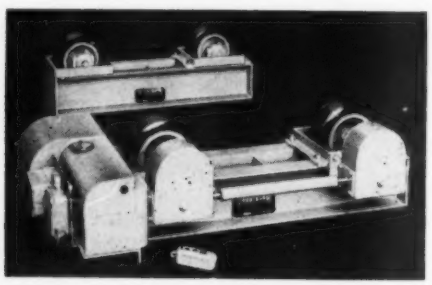

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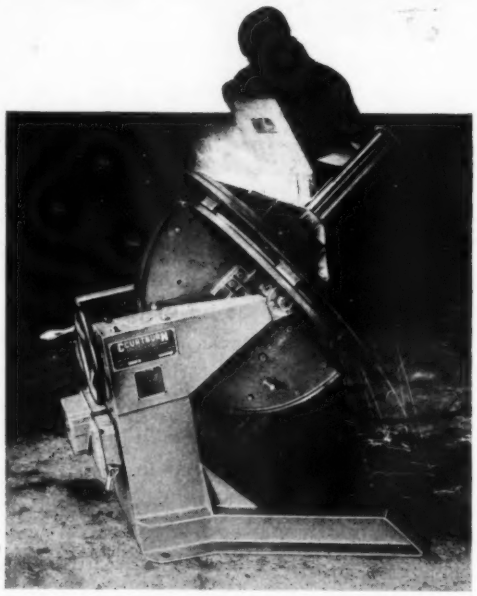

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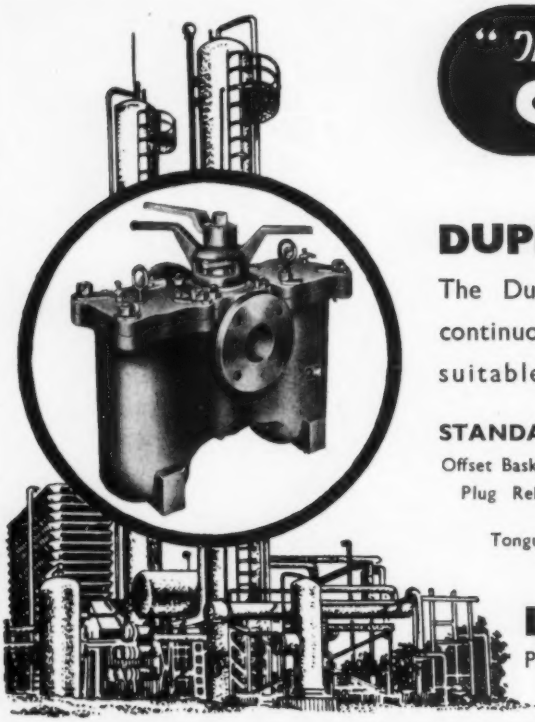

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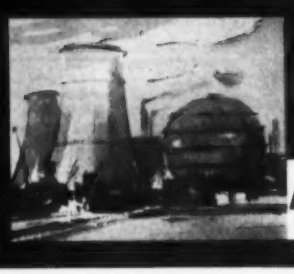

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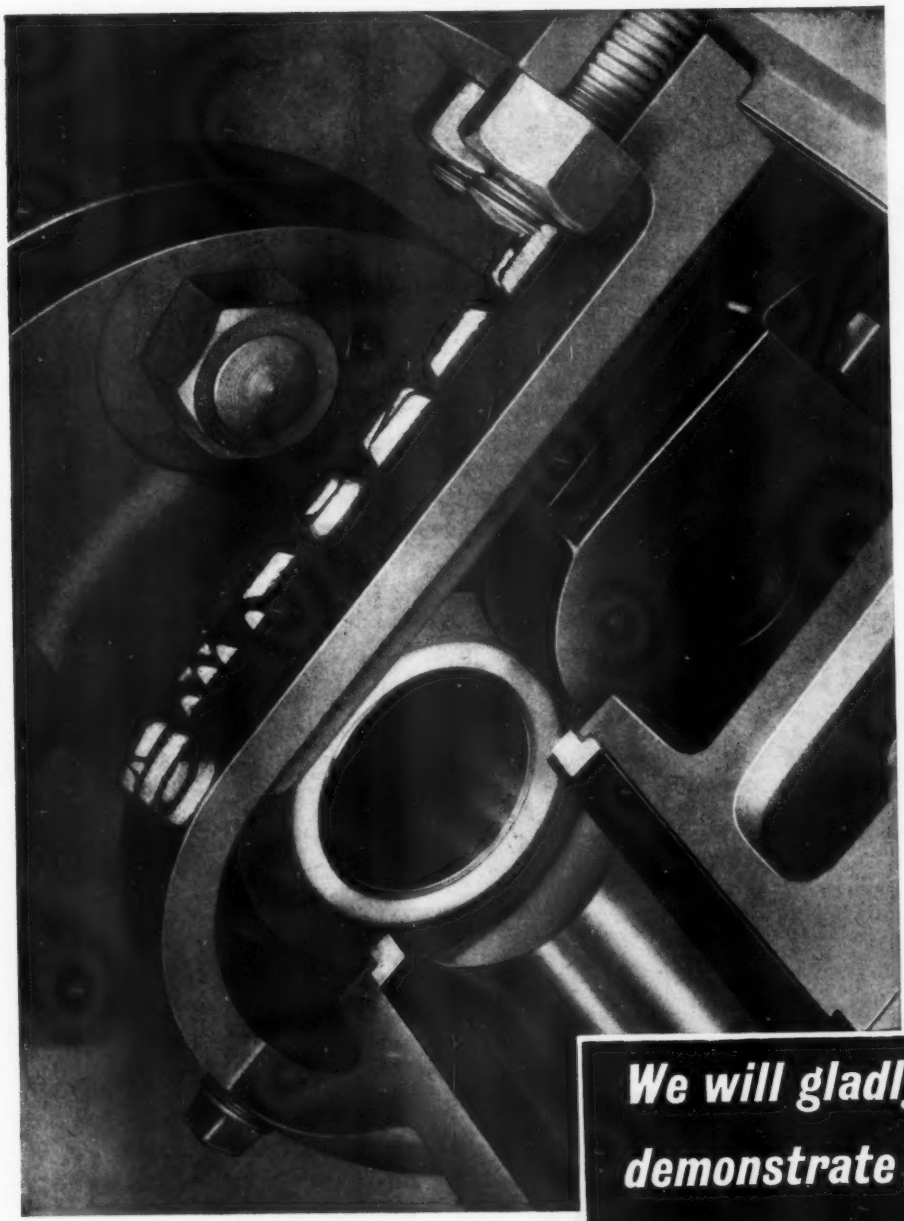

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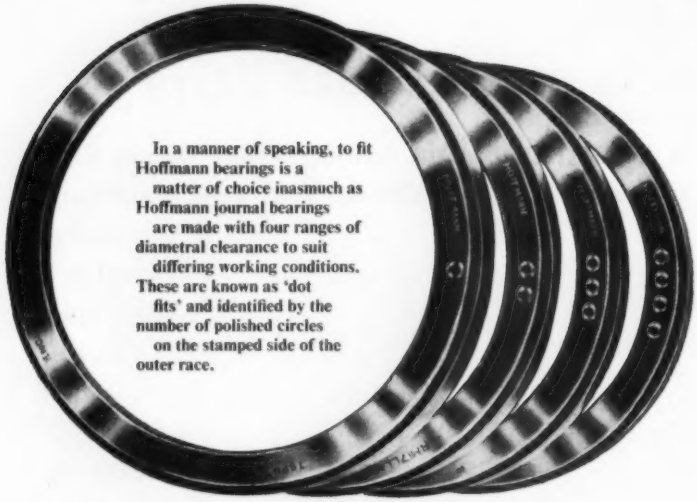

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ball and roller
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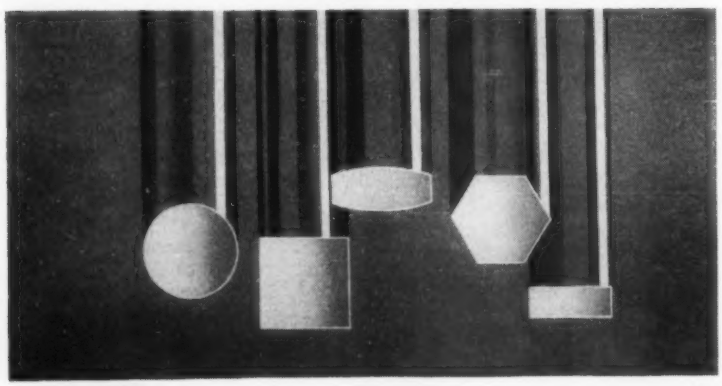

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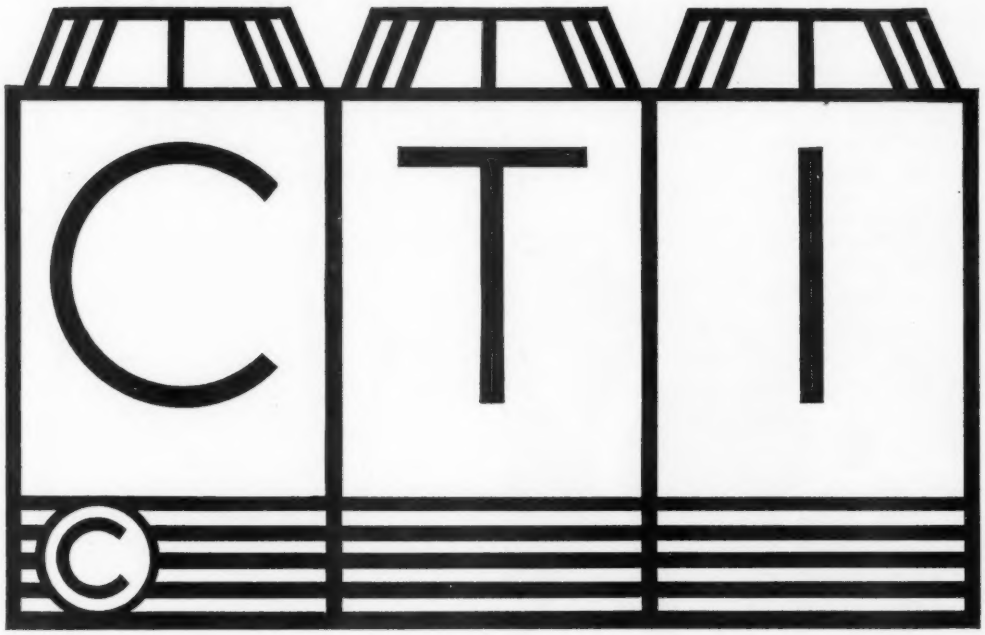

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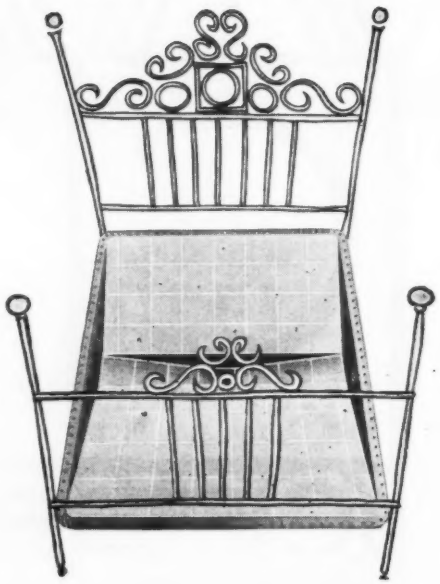

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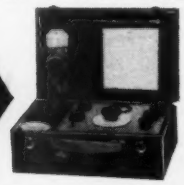

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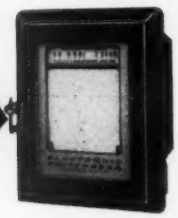

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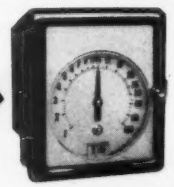

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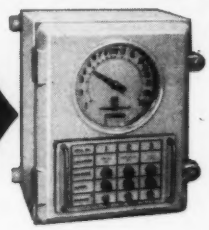

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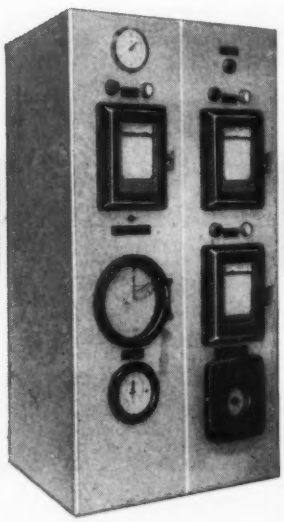

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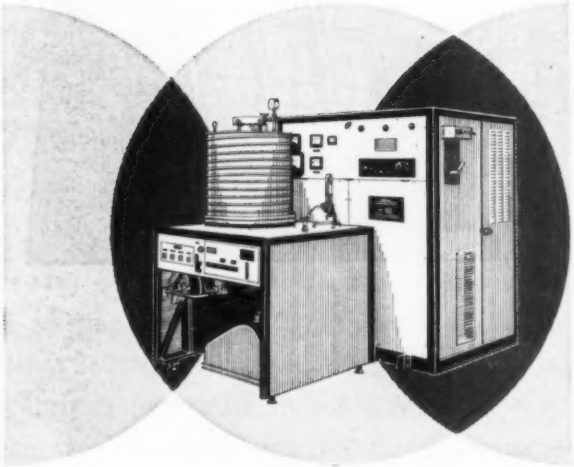

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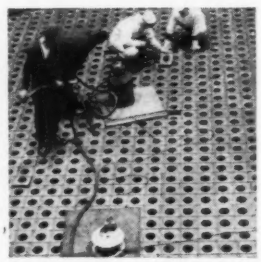

Simplex model removing dust within No. 1 reactor at Bradwell, on 25th June, 1960.
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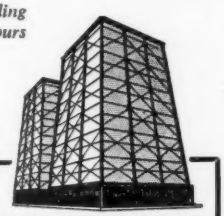

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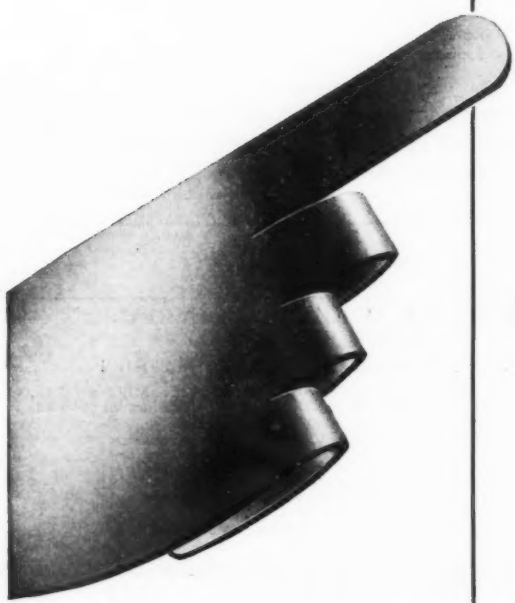

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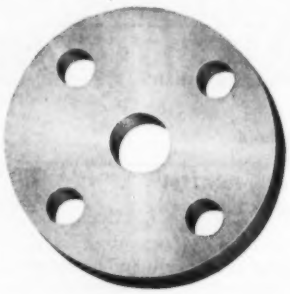

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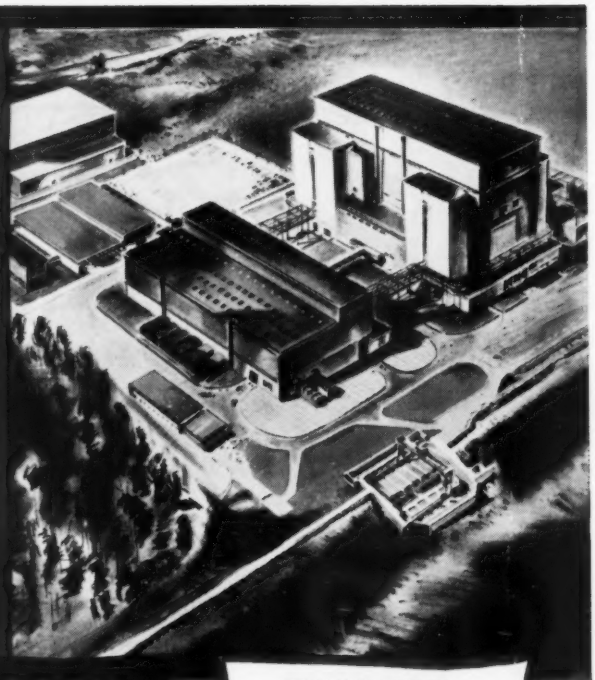

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